KLA-Tencor
Accelerating Yield

PROLITH X3.2 Training

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PC Recommendation for PROLITH X3.1

- Multi-core desktop (Workstation) preferred over laptops
- 2 GHz Intel or equivalent AMD processor (> 2.5 GHz is best choice)
- 3GB of RAM and higher (>4 GB is best choice)
- 4 cores preferred (8 cores would be best choice)
- 64-bit Vista O/S is most preferred as it does better memory management compared to XP (32 or 64 bit)
- Nvidia hardware accelerated graphics card is recommended

PROLITH X3 Releases

CY 2009

CY 2010

PROLITH X3 Platform (X3.0, X3.1, X3.2)

EUV

- Discrete source spec
- Oblique incidence*
- Multi-layer mask*
- Accelerated Mask EMF
- PSF Flare
- Stochastic resist model w/ Photoelectron model

DPL

- General Wafer Topography (LLE, LELE)
- Non-planar BARC/Resist
- Import first pass profiles for second pass simulation

ALL

- General Wafer Topography for ArF/KrF/i-line
- Stochastic for ArF/KrF
- Resist database
- Enhanced resist models
- Accelerated mask EMF
- Export GDS contours
- 1D OPC
- Parametric XY Polarization
- Image in Media
- Reflectivity w/ Topography

ACCURATE, USER FRIENDLY, FAST

* version 12.0 feature

PROLITH X3 Releases - Chronology

CY 2009

CY 2010

PROLITH X3 Platform (X3.0, X3.1, X3.2)

X3.0 – Oct-09

- General Wafer Topography
- Resist database
- 1D OPC
- GDS Export

X3.1 – Feb-10

- Stochastic Model for ArF/KrF/EUV
- Photoelectron Model for EUV
- Isothermal resist model
- Gradient parameters for full physical model

X3.2 – Nov-10

- Accelerated mask EMF (ArF/KrF/EUV)
- PSF Flare (ArF/EUV)
- Topography:
  - Import first pass to second pass (LLE)
  - Image in Media
  - Reflectivity w/ Topography
- Parametric XY Polarization
- Metrology changes
- PPI Changes

Training Outline

1. General Wafer Topography
2. Mask Model Updates
    1. Accelerated Mask EMF (ArF/KrF/EUV)
    2. 1D OPC
3. Imaging Tool Updates
    1. Sparse source shape (especially for EUV sources)
    2. Parametric XY Polarization
    3. PSF Flare (ArF/KrF/EUV)
4. Resist Model Updates
    1. Isothermal resist model
    2. Resist and material database
    3. Stochastic Lithography Modeling (Licensed Option)
    4. Photoelectron Exposure Model (Licensed Option)
5. Metrology updates
6. PPI Updates
7. Export GDS Contours

General Wafer Topography

Activating Wafer Topography – Numerics Screen

‘Check’ wafer topography on ‘numerics’page ***[Only available in Vector Image Calculation Mode]***

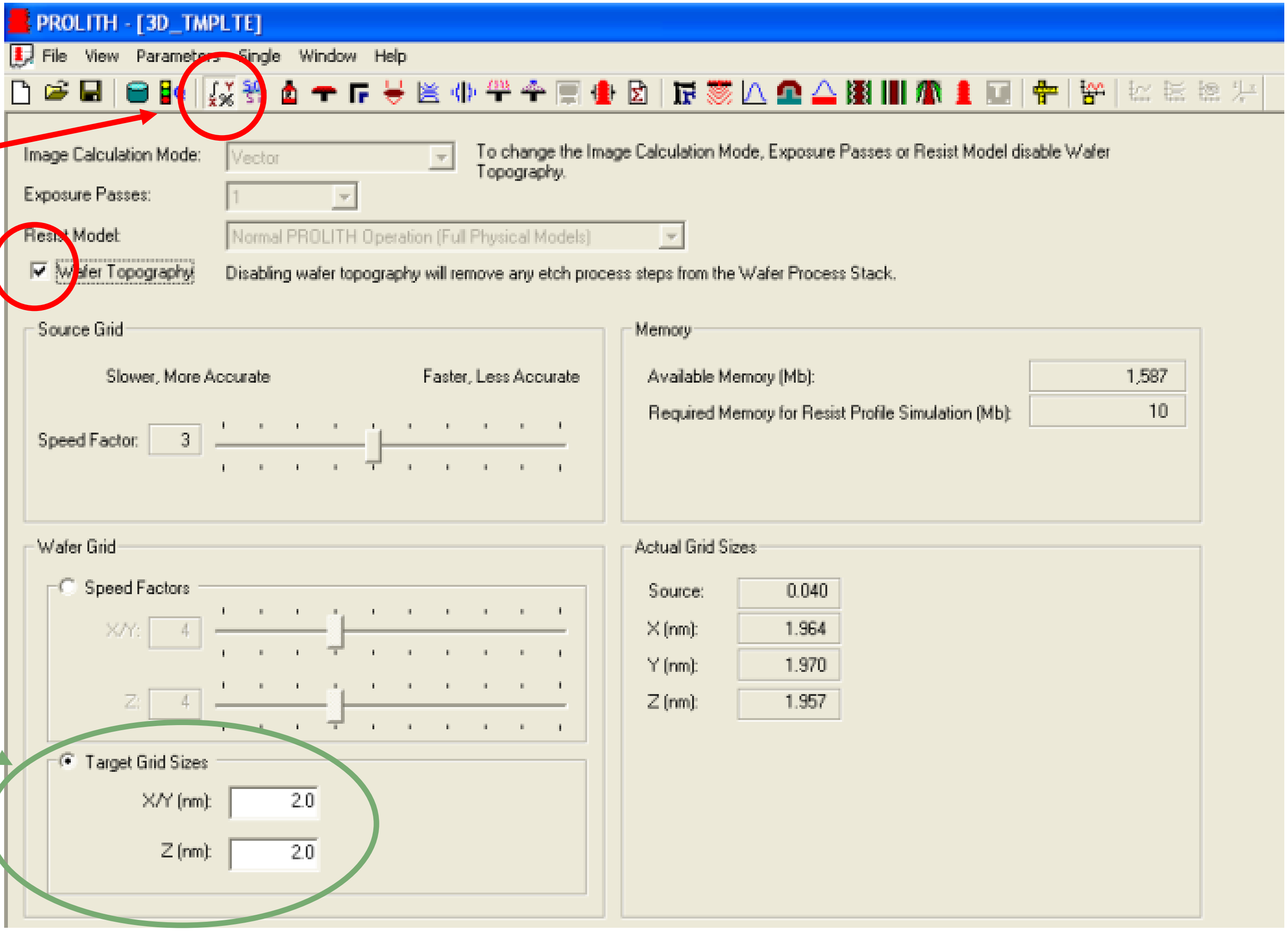


Image Calculation Mode: Vector

To change the Image Calculation Mode, Exposure Passes or Resist Model disable Wafer Topography.

Exposure Passes: 1

Resist Model: Normal PROLITH Operation (Full Physical Models)

☑ Wafer Topography

Disabling wafer topography will remove any etch process steps from the Wafer Process Stack.

Source Grid

Slower, More Accurate — Faster, Less Accurate

Speed Factor: 3

Memory

Available Memory (Mb): 1,587

Required Memory for Resist Profile Simulation (Mb): 10

Wafer Grid

○ Speed Factors

X/Y: 4

Z: 4

● Target Grid Sizes

X/Y (nm): 2.0

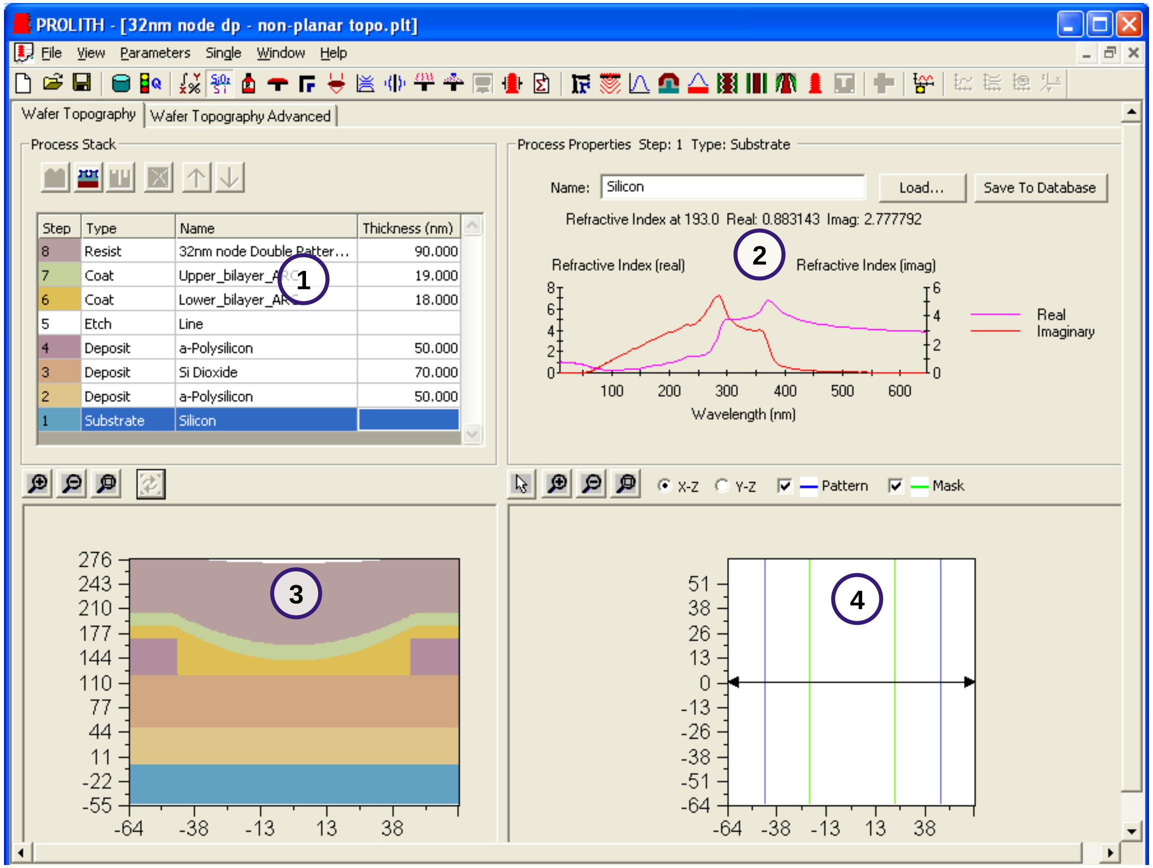
Z (nm): 2.0

Actual Grid Sizes

Source:	0.040
X (nm):	1.964
Y (nm):	1.970
Z (nm):	1.957

Best practice to choose ***‘Target Grid Sizes’ [2 nm recommended]***

Wafer Processes Screen



Process Stack

Step	Type	Name	Thickness (nm)
8	Resist	32nm node Double Patter...	90.000
7	Coat	Upper_bilayer_ARC	19.000
6	Coat	Lower_bilayer_AR	18.000
5	Etch	Line	
4	Deposit	a-Polysilicon	50.000
3	Deposit	Si Dioxide	70.000
2	Deposit	a-Polysilicon	50.000
1	Substrate	Silicon	

Process Properties Step: 1 Type: Substrate

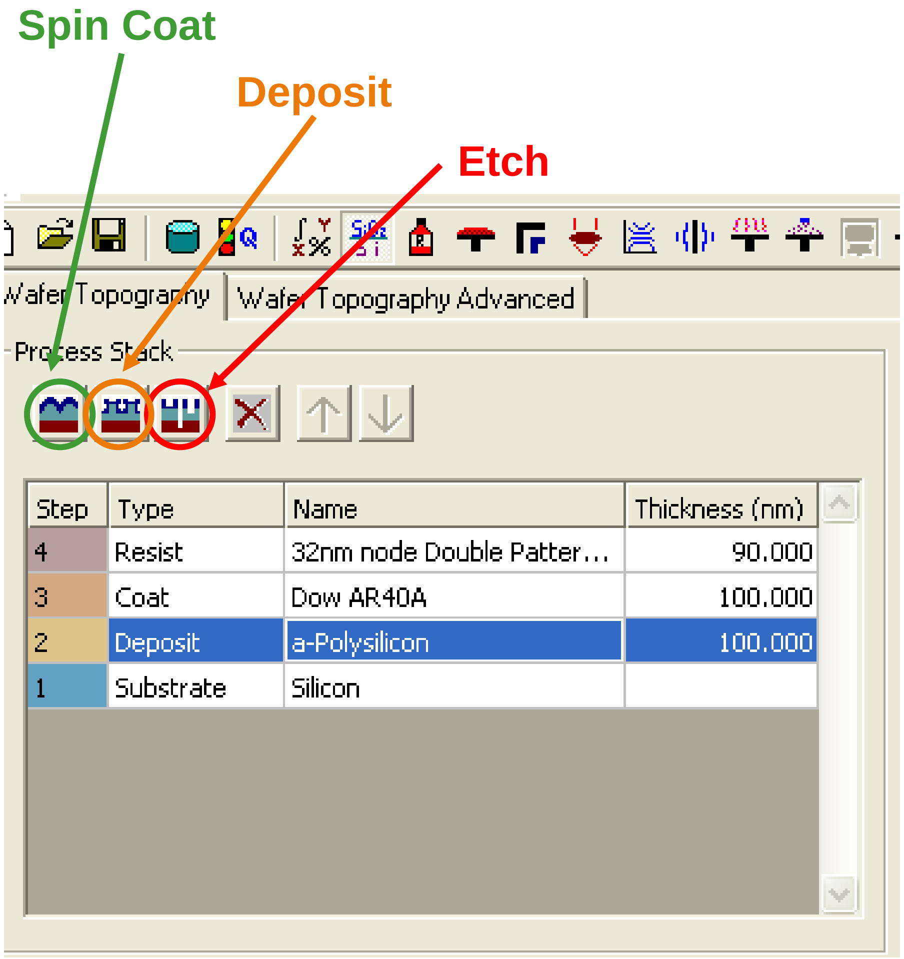
Name: Silicon Load... Save To Database

Refractive Index at 193.0 Real: 0.883143 Imag: 2.777792

● X-Z ○ Y-Z ☑ Pattern ☑ Mask

1. Process Stack
   - Add process steps
   - Remove process steps
   - Organize process stack
2. Process Properties
   - Load materials
   - Set material optical properties
   - Set coating characteristics
   - Set etch pattern and parameters
3. Wafer cross section
4. Topography pattern/mask Image

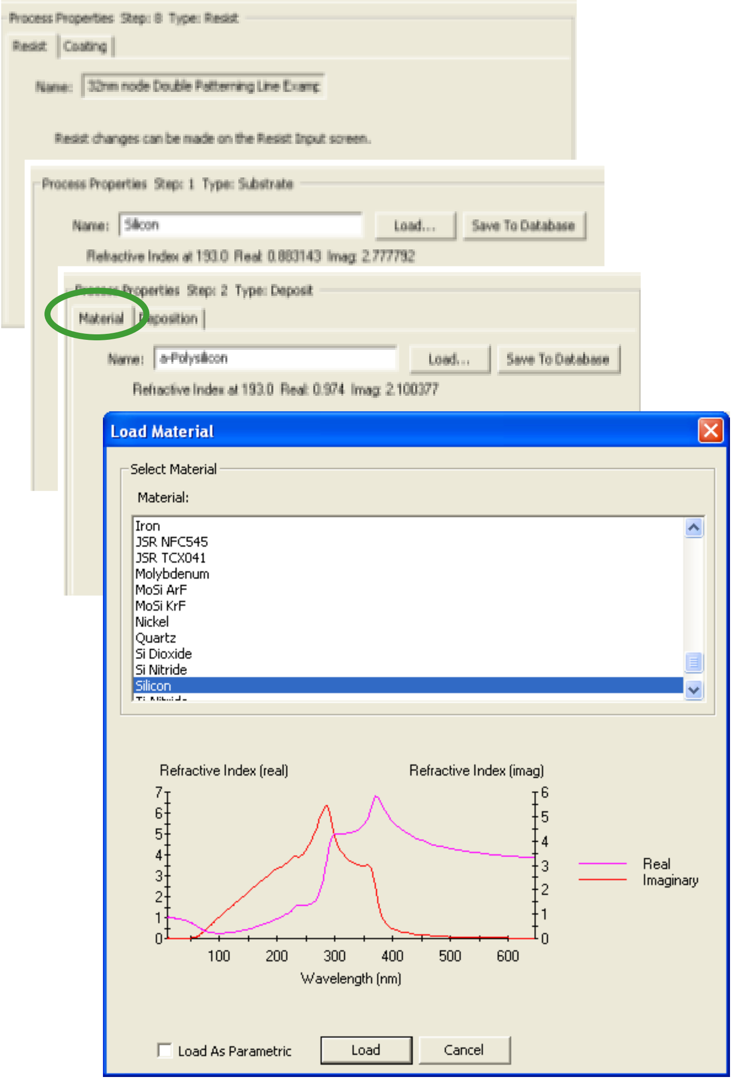
Wafer Processes



Step	Type	Name	Thickness (nm)
4	Resist	32nm node Double Patter…	90.000
3	Coat	Dow AR40A	100.000
2	Deposit	a-Polysilicon	100.000
1	Substrate	Silicon	

- Process stack can contain up to 99 process steps
- Add steps using the buttons
  - New steps are inserted above the selected step
  - Resist step is controlled by loading materials from resist screen
  - Wafer topography must be enabled to add an etch step, or to specify the nature of a deposition or a spin coat step
  - Only 1 etch step can be defined
  - Only 1 layer can be applied above the resists, either a CEL or a material

Resist and Material Properties



Process Properties Step: 8 Type: Resist

Name: 32nm node Double Patterning Line Examp

Resist changes can be made on the Resist Input screen.

Process Properties Step: 1 Type: Substrate

Name: Silicon

Refractive Index at 193.0 Real: 0.883143 Imag: 2.777792

Process Properties Step: 2 Type: Deposit

Name: a-Polysilicon

Refractive Index at 193.0 Real: 0.974 Imag: 2.100377

Load Material

Select Material

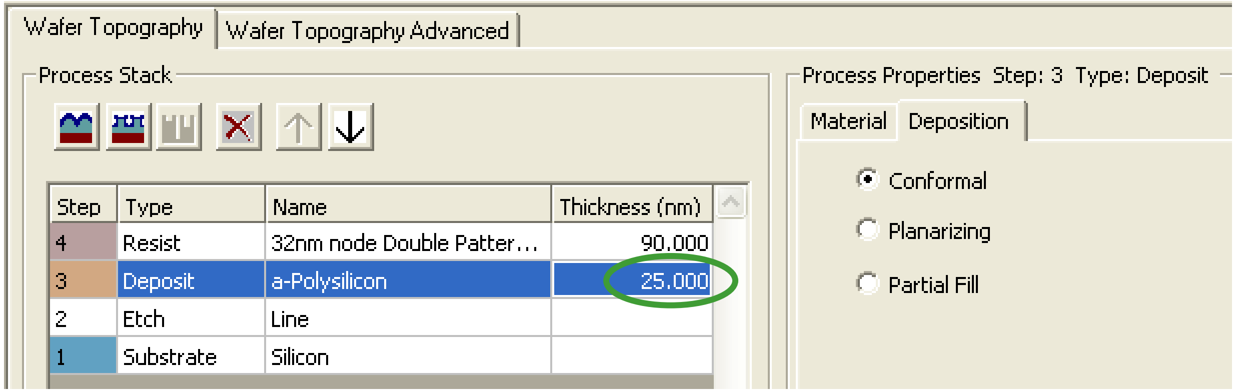
Material:

Iron
JSR NFC545
JSR TCX041
Molybdenum
MoSi ArF
MoSi KrF
Nickel
Quartz
Si Dioxide
Si Nitride
Silicon

☐ Load As Parametric

- Resist details only display on the wafer processes screen, it must be loaded on the resist page.
- When wafer topography is active, coat and deposition methods can be defined (see following slides)
- Coat, deposit and substrate materials can be loaded as parametric (on material tab)
  - User defined n & k values can be supplied
  - Optical properties are for selected wavelength
- Database materials can contain data from multiple wavelengths

Deposition Processes: Conformal



Process Stack

Step	Type	Name	Thickness (nm)
4	Resist	32nm node Double Patter...	90.000
3	Deposit	a-Polysilicon	25.000
2	Etch	Line	
1	Substrate	Silicon	

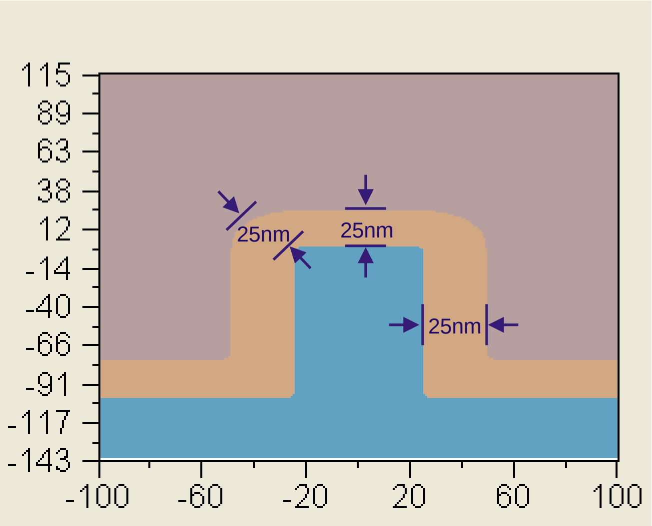
Process Properties Step: 3 Type: Deposit

● Conformal

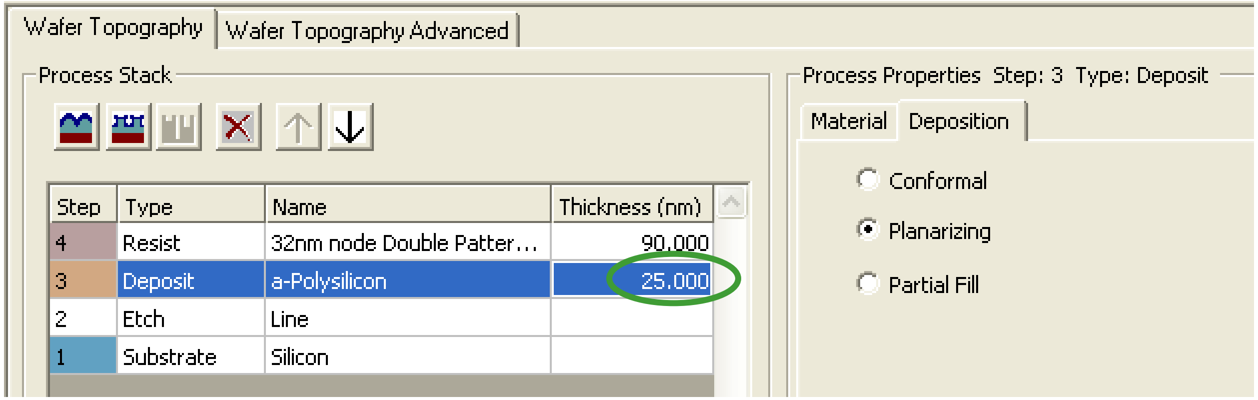
○ Planarizing

○ Partial Fill

- A conformal deposition is applied the current topography stack.
- The layer thickness is defined in the wafer process grid..
- Depositions may be stacked, but cannot be place over a spin coat.
- The nature of the deposited material is defined on the ‘material’ tab.



Deposition Processes: Planarizing



Process Stack

Step	Type	Name	Thickness (nm)
4	Resist	32nm node Double Patter...	90.000
3	Deposit	a-Polysilicon	25.000
2	Etch	Line	
1	Substrate	Silicon	

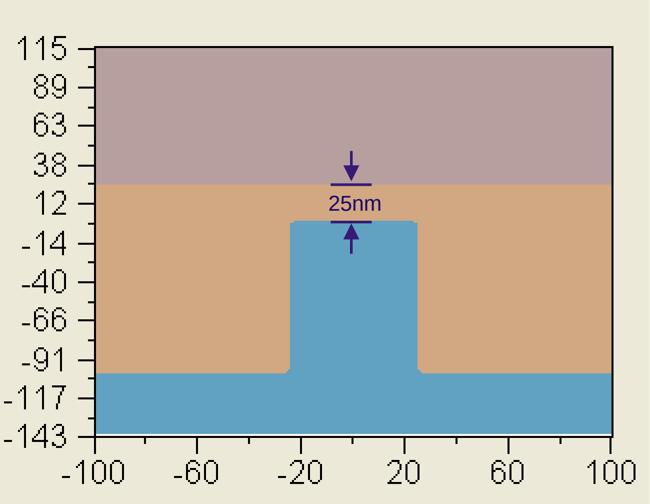
Process Properties Step: 3 Type: Deposit

○ Conformal

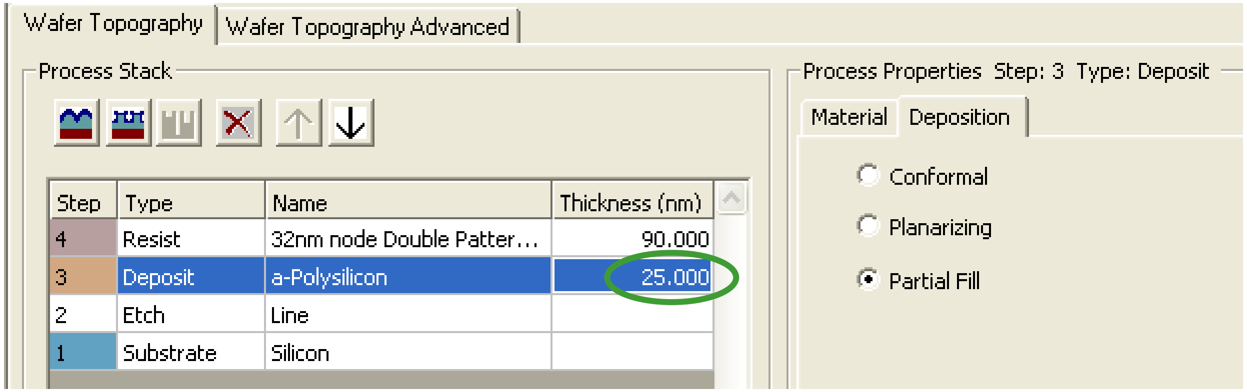
● Planarizing

○ Partial Fill

- A planar deposition is applied above the current topography stack.
- The layer thickness is defined in the wafer process grid, and is measured from the ***highest point*** on the prior topography.
- This is deposit behavior in PROLITH V12
- Depositions may be stacked, but cannot be place over a spin coat.
- The nature of the deposited material is defined on the 'material' tab.



Deposition Processes: Partial Fill



Wafer Topography | Wafer Topography Advanced

Process Stack

Step	Type	Name	Thickness (nm)
4	Resist	32nm node Double Patter…	90.000
3	Deposit	a-Polysilicon	25.000
2	Etch	Line	
1	Substrate	Silicon	

Process Properties Step: 3 Type: Deposit

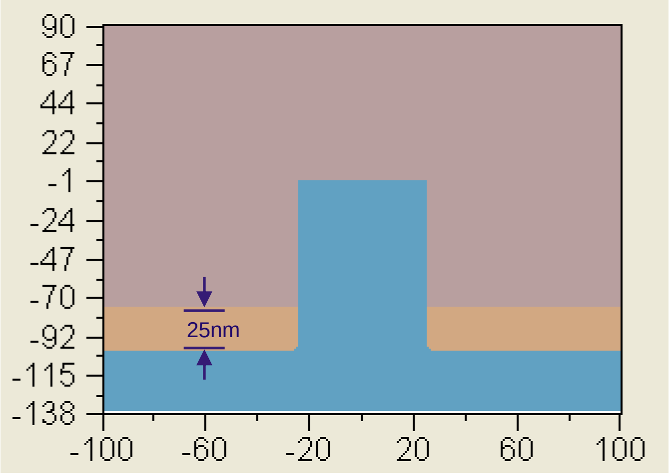
Material | Deposition

○ Conformal

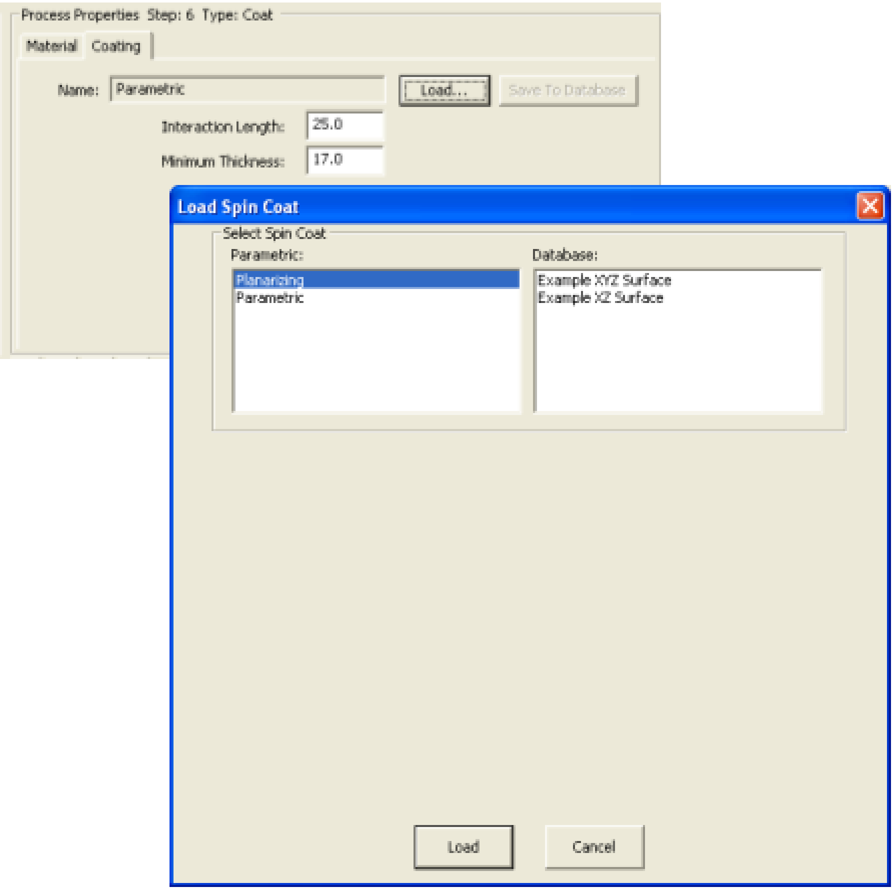
○ Planarizing

● Partial Fill

- A planar deposition is applied to the base of the current topography stack.
- The layer thickness is defined in the wafer process grid, and is measured from the ***lowest point*** on the prior topography.
- Depositions may be stacked, but cannot be place over a spin coat.
- The nature of the deposited material is defined on the ‘material’ tab.



Coat Processes



Process Properties Step: 6 Type: Coat

Name: Parametric

Interaction Length: 25.0

Minimum Thickness: 17.0

Load Spin Coat

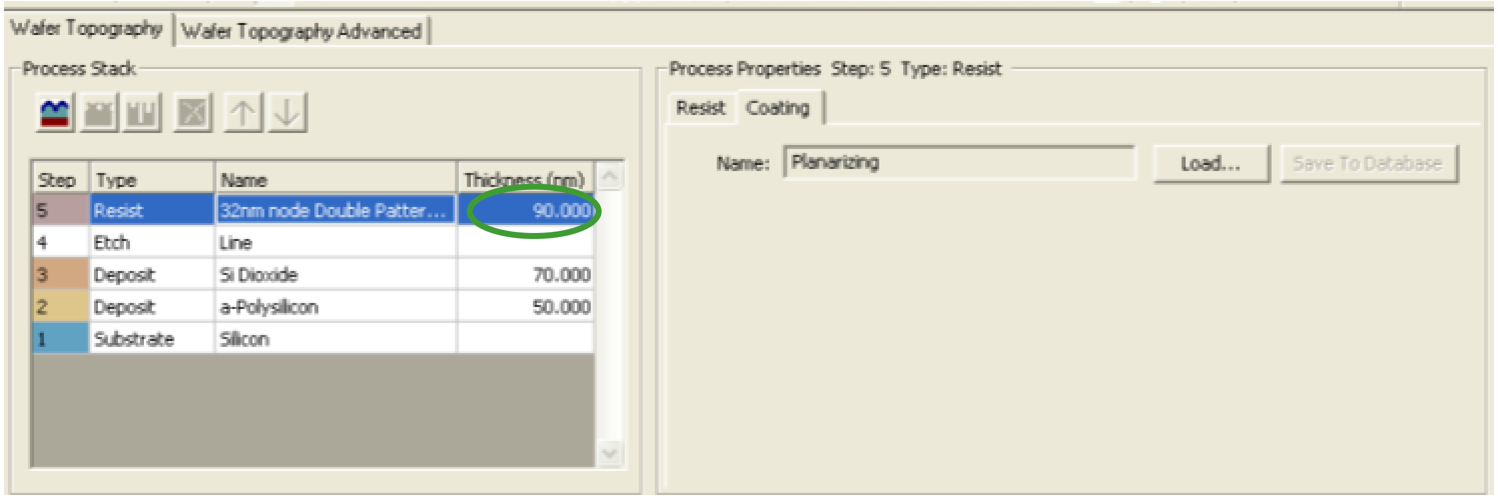
Select Spin Coat

Parametric:
- Planarizing
- Parametric

Database:
- Example XYZ Surface
- Example XZ Surface

- Coat surfaces may be defined in one of three ways
  - Planarizing coat (same functionality as PROLITH V12)
  - Parametric spin coat model
  - User definable database file
- The user ‘loads’ the coat process using the same paradigm utilized for other processes which can be defined parametrically or by database item (e.g. sourceshape, polarization and mask)
  - Parametric option appear in the left window pane
  - Database items appear in the right window pane.

Spin Processes: Planarizing



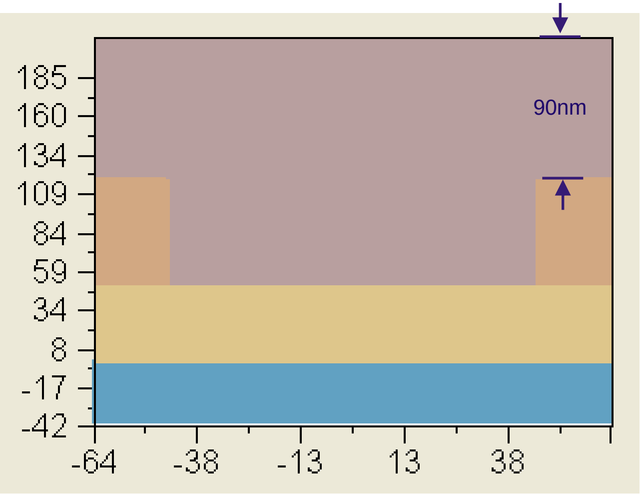
Process Stack

Step	Type	Name	Thickness (nm)
5	Resist	32nm node Double Patter...	90.000
4	Etch	Line	
3	Deposit	Si Dioxide	70.000
2	Deposit	a-Polysilicon	50.000
1	Substrate	Silicon	

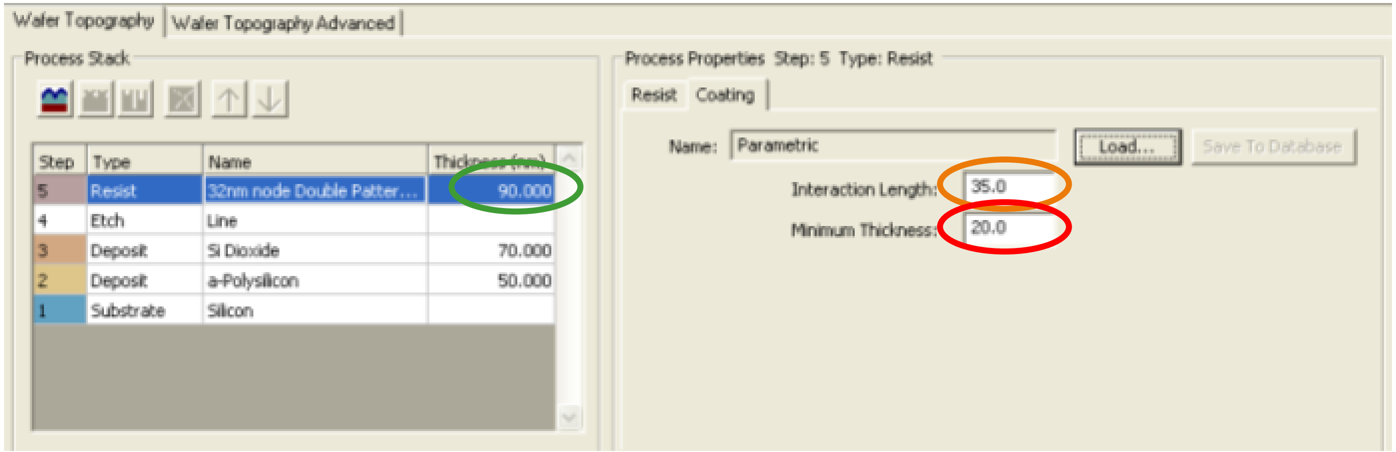
Process Properties Step: 5 Type: Resist

Name: Planarizing

- A planar coat is applied above the current topography stack.
- The layer thickness is defined in the wafer process grid, and is measured from the ***highest point*** on the prior topography.
- This is coat behavior in PROLITH V12
- Spin coats may be stacked or applied over etches and depositions.
- The nature of the coated material is defined on the ‘material’ tab.



Spin Processes: Parametric



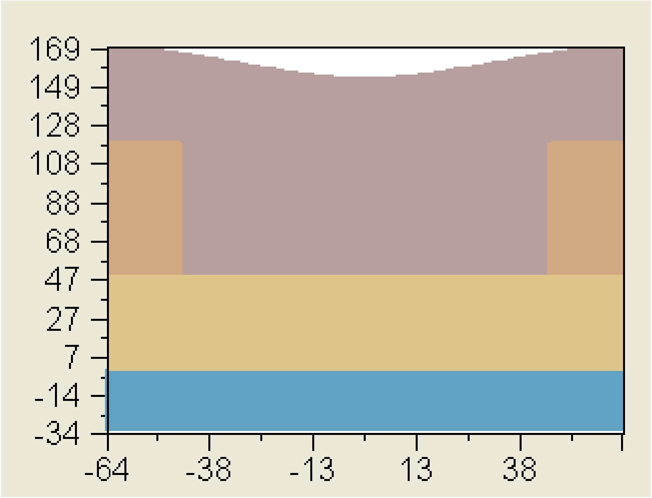
Step	Type	Name	Thickness (nm)
5	Resist	32nm node Double Patter...	90.000
4	Etch	Line	
3	Deposit	Si Dioxide	70.000
2	Deposit	a-Polysilicon	50.000
1	Substrate	Silicon	

Name: Parametric

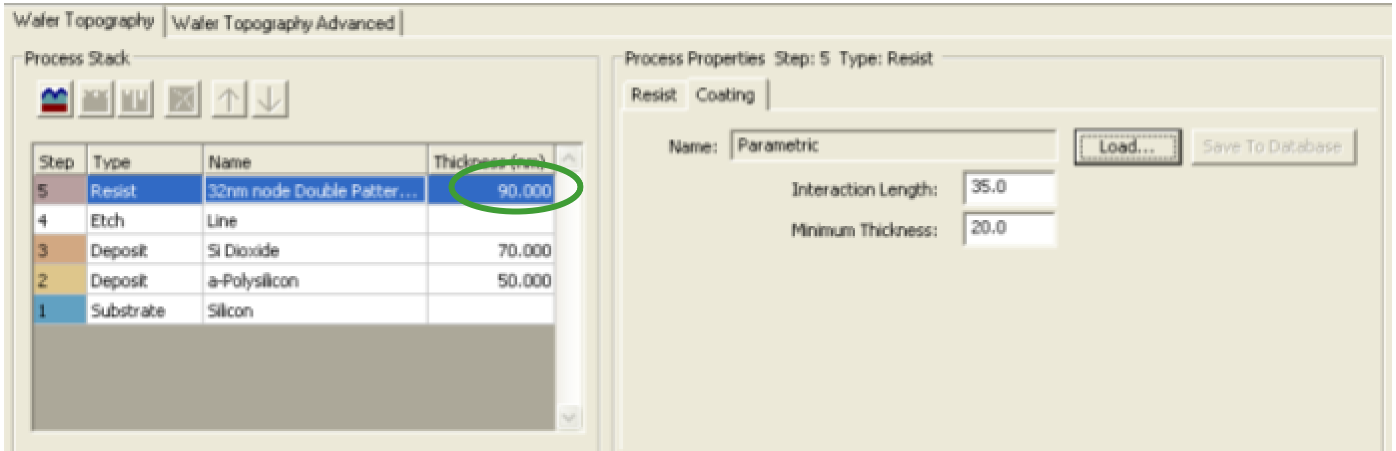
Interaction Length: 35.0

Minimum Thickness: 20.0

- The parametric spin coat model has three input parameters
  1. **Nominal thickness (nm)**
  2. **Interaction Length (nm)**
  3. **Minimum Thickness (nm)**
- The purpose of each input parameter will be outlined on the following slides



Spin Processes: Parametric – Nominal Thickness



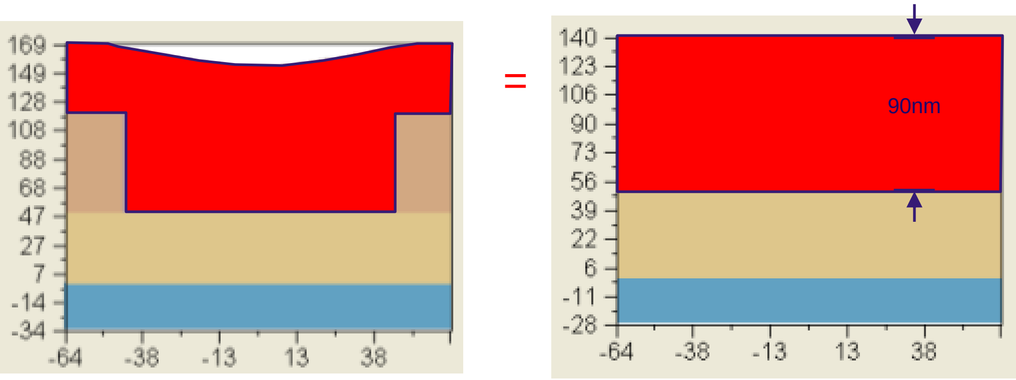
Step	Type	Name	Thickness (nm)
5	Resist	32nm node Double Patter...	90.000
4	Etch	Line	
3	Deposit	Si Dioxide	70.000
2	Deposit	a-Polysilicon	50.000
1	Substrate	Silicon	

Name: Parametric

Interaction Length: 35.0

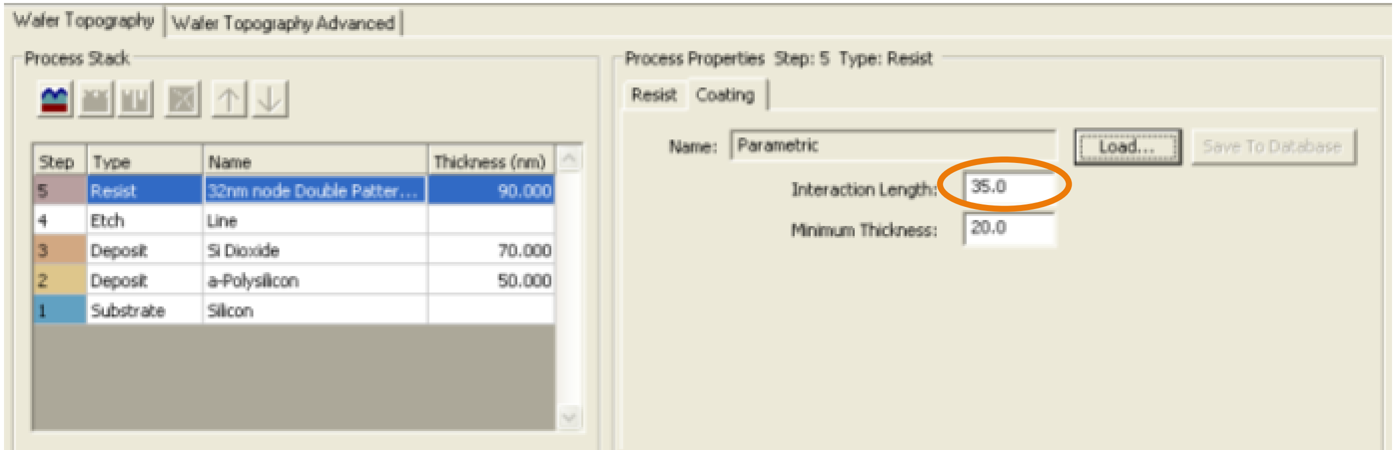
Minimum Thickness: 20.0

- **Nominal thickness (nm)**
  - This parameters defines the thickness that the spin coat film would have, when applied to a planar substrate.
  - The PROLITH coating algorithm generates a coating which has an equivalent volume to the planar case.



Resist volumes are equal when nominal thickness is the same

Spin Processes: Parametric – Interaction Length



Process Stack

Step	Type	Name	Thickness (nm)
5	Resist	32nm node Double Patter...	90.000
4	Etch	Line	
3	Deposit	Si Dioxide	70.000
2	Deposit	a-Polysilicon	50.000
1	Substrate	Silicon	

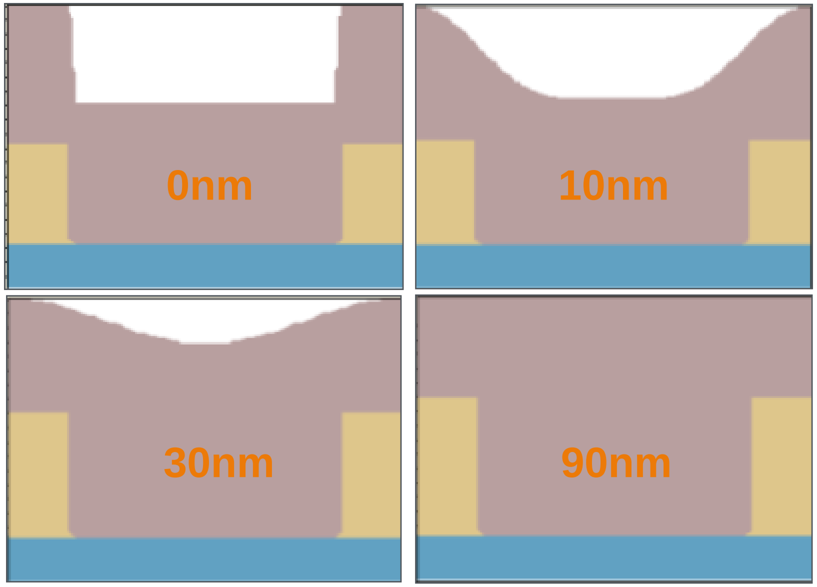
Process Properties Step: 5 Type: Resist

Name: Parametric

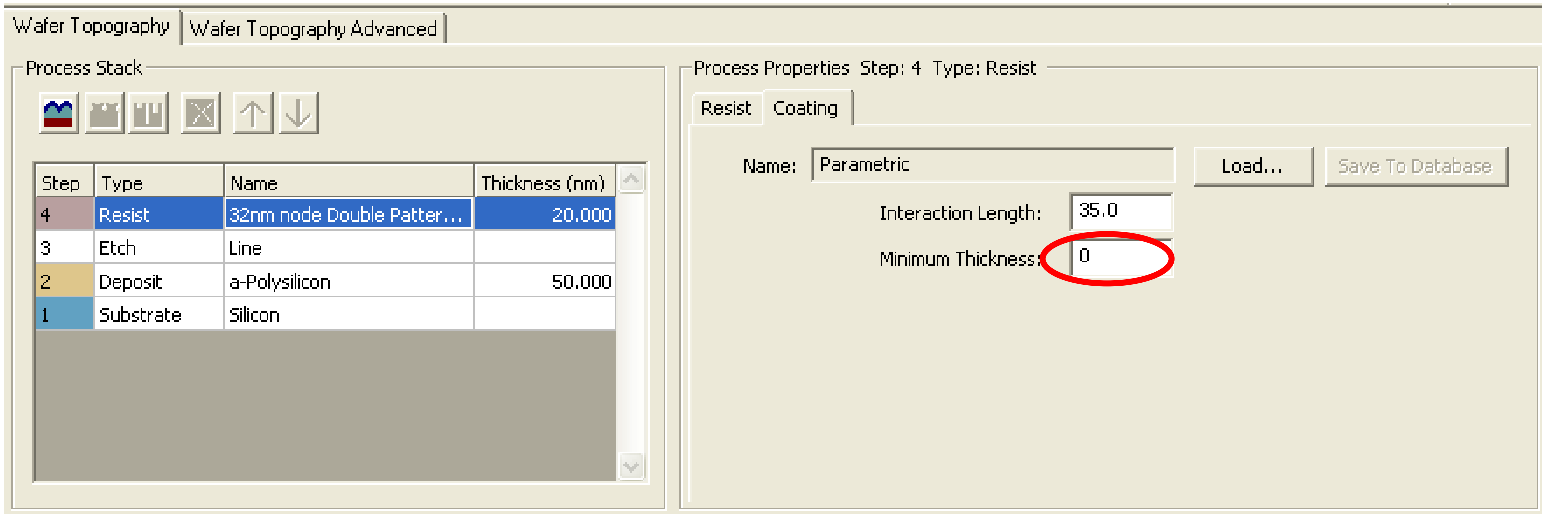
Interaction Length: 35.0

Minimum Thickness: 20.0

- **Interaction Length (nm)**
  - The interaction length specifies the half-width of the Gaussian used to convolve the topography shape
  - High number = more smoothing



Spin Processes: Parametric – Minimum Thickness



Wafer Topography | Wafer Topography Advanced

Process Stack

Step	Type	Name	Thickness (nm)
4	Resist	32nm node Double Patter…	20.000
3	Etch	Line	
2	Deposit	a-Polysilicon	50.000
1	Substrate	Silicon	

Process Properties Step: 4 Type: Resist

Resist | Coating

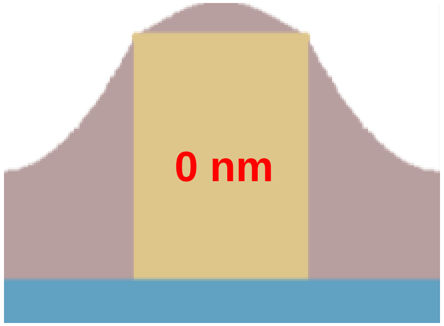
Name: Parametric

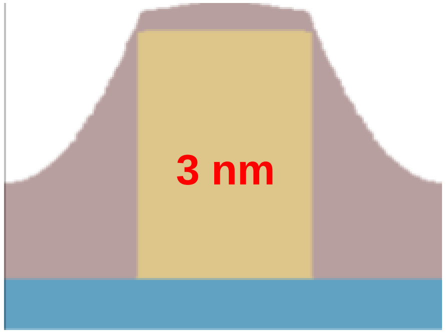
Load... | Save To Database

Interaction Length: 35.0

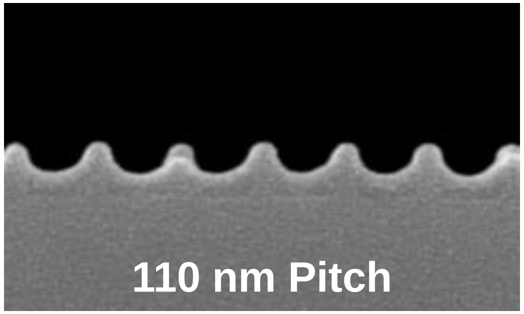
Minimum Thickness: 0

- **Minimum Thickness (nm)**
- When the coating thickness is less than the topography step height dewetting of feature corners is often predicted. [not observed in Expt.]
- The minimum thickness constraint defines prevents the material thickness going below a defined value yielding more realistic coverage.

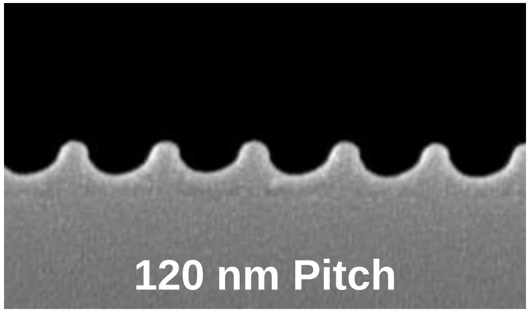




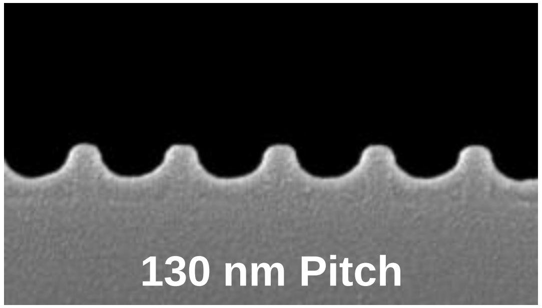
Spin Coat Model Example Calibration: Experimental BARC for SPIE Paper



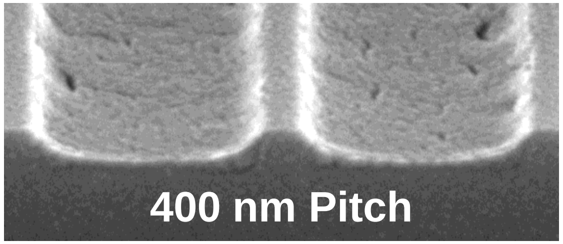
110 nm Pitch



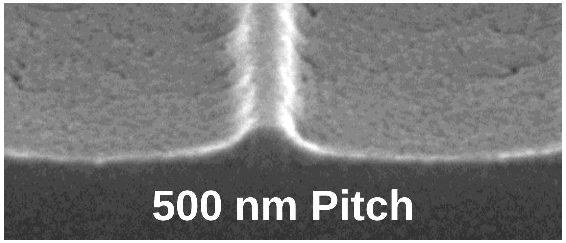
120 nm Pitch



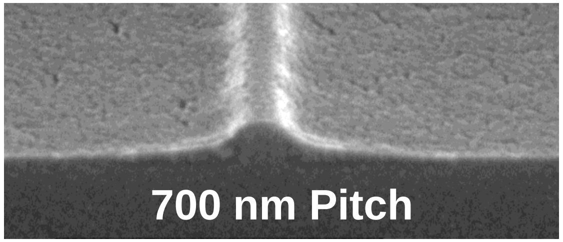
130 nm Pitch



400 nm Pitch



500 nm Pitch



700 nm Pitch

- Analysis of X-section images shows
  1. Thickness of BARC over steps approximately 12nm (10 – 15 nm)
     Note: SEM images of etched collected also
  2. Thickness of BARC center of gap is always approximately flat wafer thickness (26nm).
  3. Estimate of error in measurement ±3 nm

Experimental Topography Set-Up

- Lithography on ASML Twinscan /1900i and TEL Lithius i+ cluster
  - 1.0 NA, Dipole 35° Y, 0.96σo/0.69σi, X Polarization
  - 6% AttPSM Mask
  - Very long lines (mm)

- Etch on LAM 2300 VERSYS
  - **BARC Etch:** CF4-based recipe with end-point detection
  - **Silicon Etch:** CH2F2/SF6-based recipe. Timed for etch depth target
  - **Resist strip:** O2-based dry strip recipe

- Etched Structures
  - Nominal 40 nm Width, 60 nm Deep, Etched Silicon
  - Pitches vary from 110 nm through 700 nm

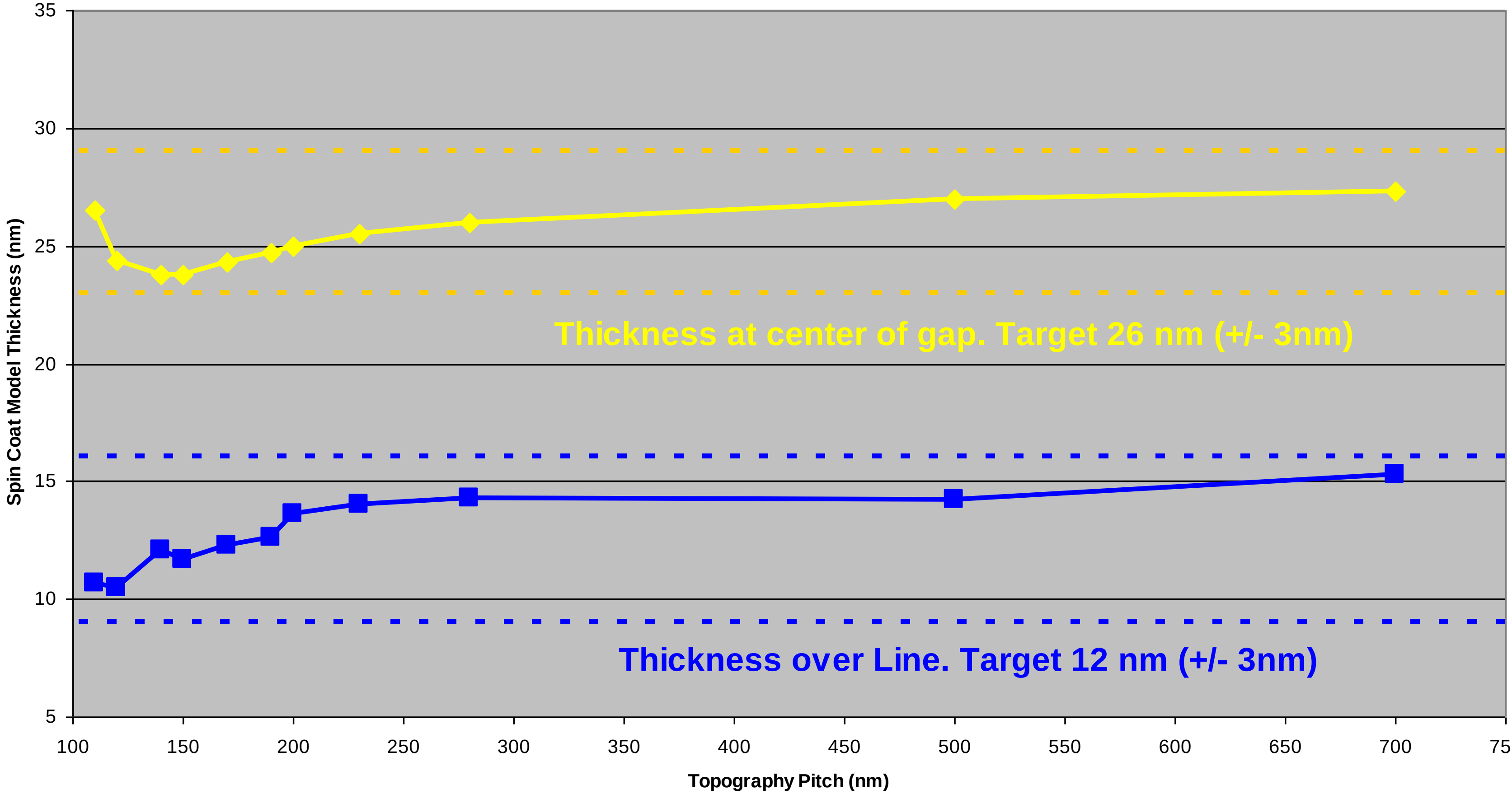
Spin Coat Model Calibration

- For each pitch of interest etched topography was assumed to be ideal, i.e. 40 nm wide and 60 nm deep with rectangular profile.
- The BARC thickness above the center of the etched line and the middle of the etch gap were measured for each pitch (110 nm, 120 nm, 140 nm, 150 nm, 170 nm, 190 nm, 200 nm, 230 nm, 280 nm, 500 nm, 700 nm)
- Spin coat parameters were manually adjusted with goal of 12 nm BARC thickness above the line center and 26 nm BARC thickness at middle of gap.
- Good results (within measurement error) were obtained:

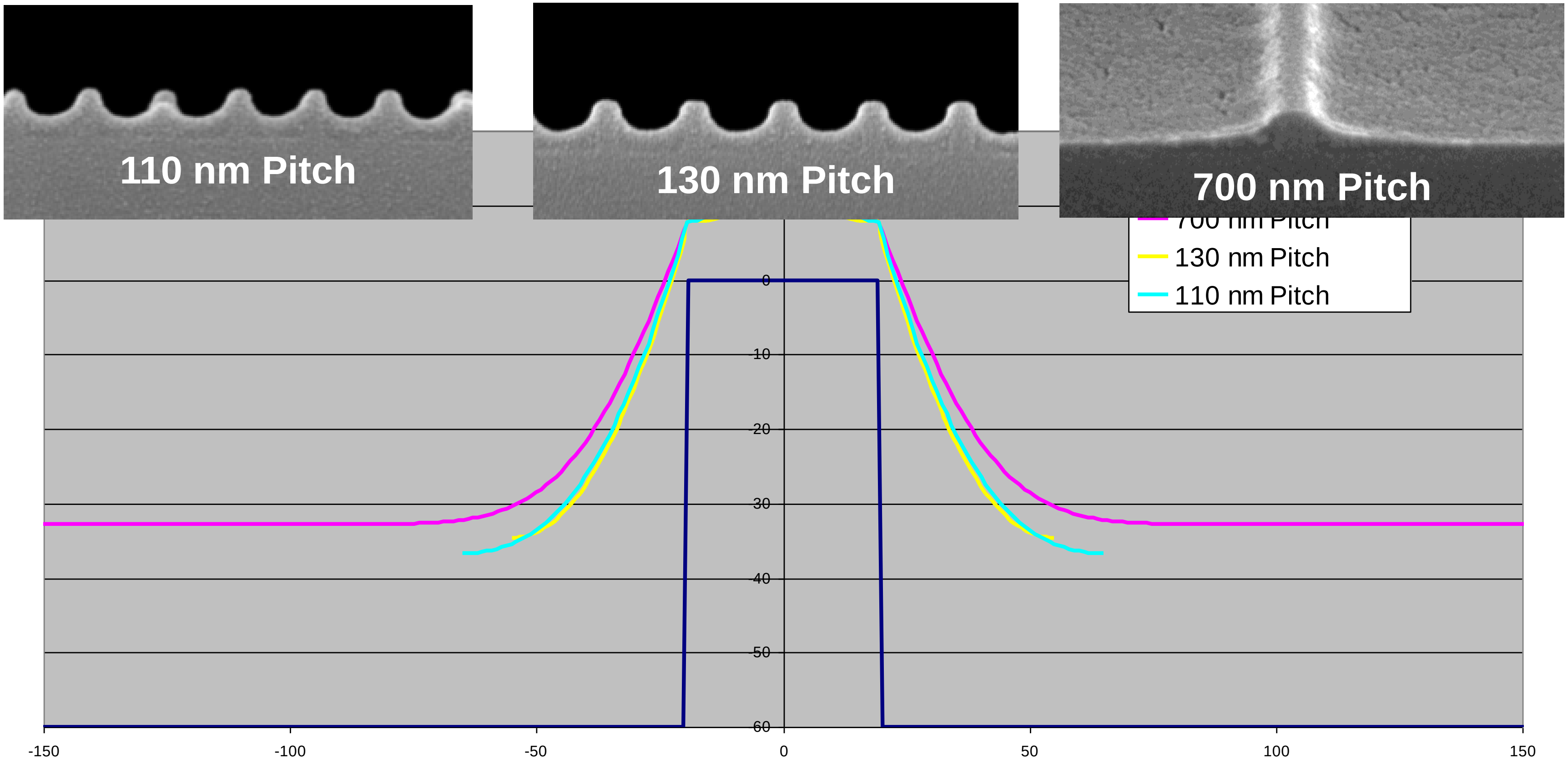
  Nominal thickness = 28 nm
  Interaction Length = 19 nm
  Minimum Thickness = 8 nm

Spin Coat Model Calibration Results

BARC spin coat model predictions over 40 nm wide, 60 nm deep etched silicon for 28 nm nominal thickness, 19 nm interaction length and 8 nm minimum thickness

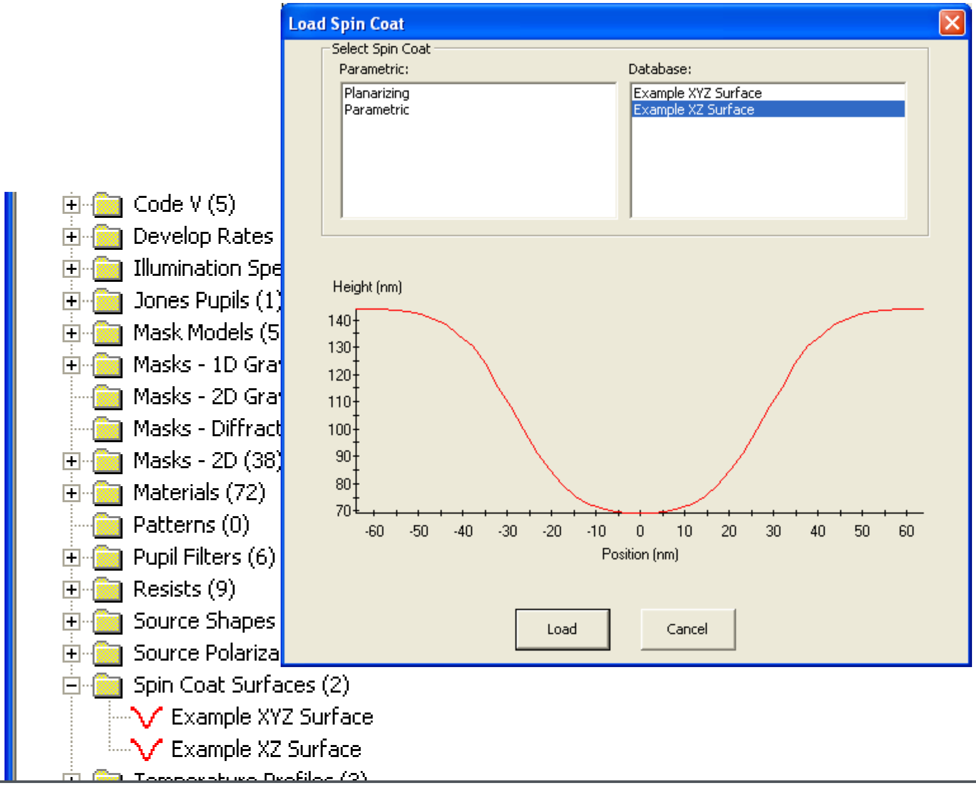


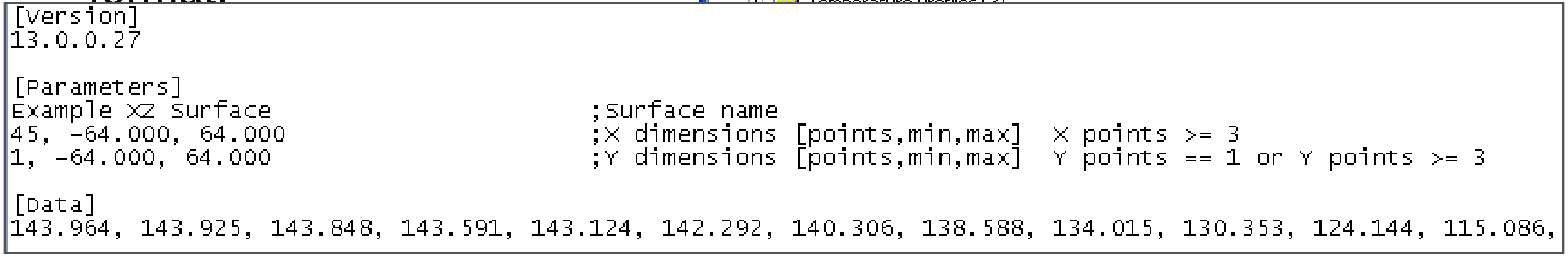
Calibrated Spin Coat Model: Profile Comparisons



Import Spin Coat Surface

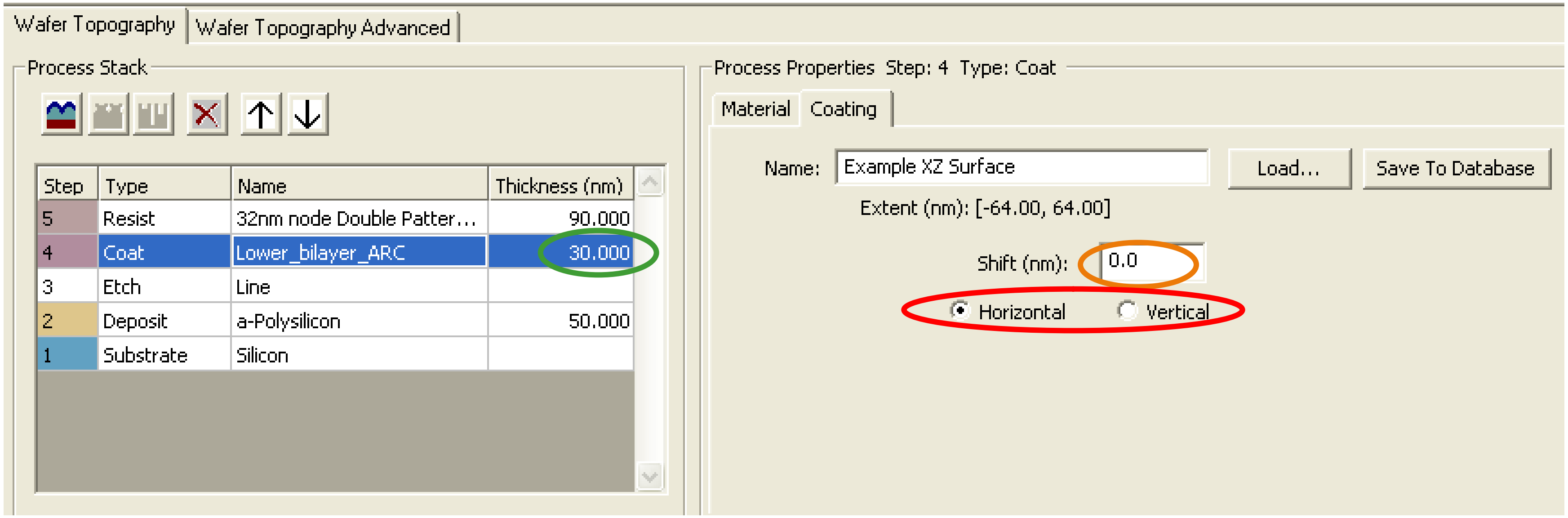
- If the spin coat model cannot create the desired shape, the user can add their own arbritrary coating surface as a database item. Specifying height versus position.
- Two examples (2D and 3D) are provided in the database. These can be exported to show the file format.





```
[Version]
13.0.0.27

[Parameters]
Example XZ Surface                       ;Surface name
45, -64.000, 64.000                      ;X dimensions [points,min,max]  X points >= 3
1, -64.000, 64.000                       ;Y dimensions [points,min,max]  Y points == 1 or Y points >= 3

[Data]
143.964, 143.925, 143.848, 143.591, 143.124, 142.292, 140.306, 138.588, 134.015, 130.353, 124.144, 115.086,
```

Import Spin Coat Surface



Step	Type	Name	Thickness (nm)
5	Resist	32nm node Double Patter...	90.000
4	Coat	Lower_bilayer_ARC	30.000
3	Etch	Line	
2	Deposit	a-Polysilicon	50.000
1	Substrate	Silicon	

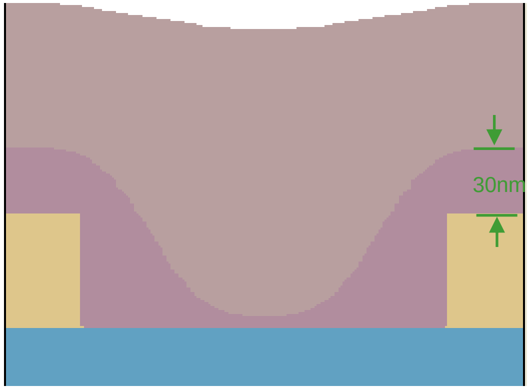
Name: Example XZ Surface

Extent (nm): [-64.00, 64.00]

Shift (nm): 0.0

● Horizontal ○ Vertical

- **Thickess is defined between highest point on stack and highest point on imported surface.**
- **Surface can be shifted**
- **1-D Surfaces are always defined in the x direction, these radio buttons are used to rotate the data into the y-direction**

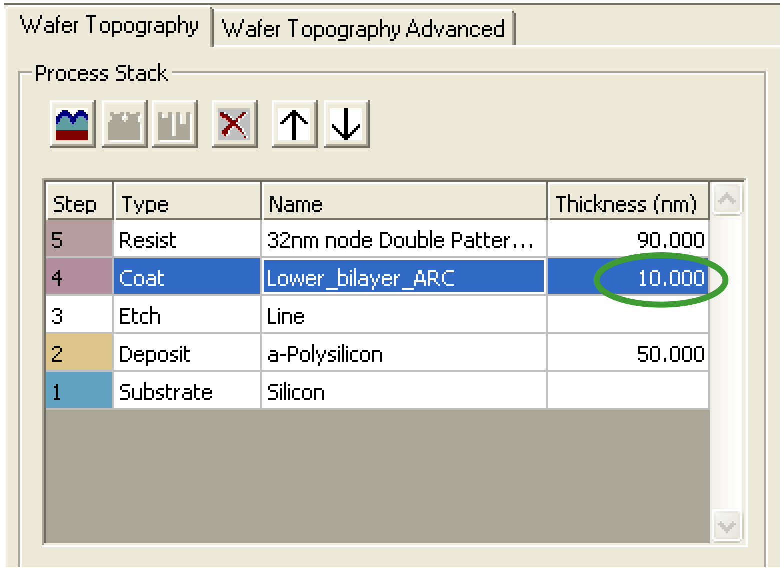


Import Spin Coat Surface

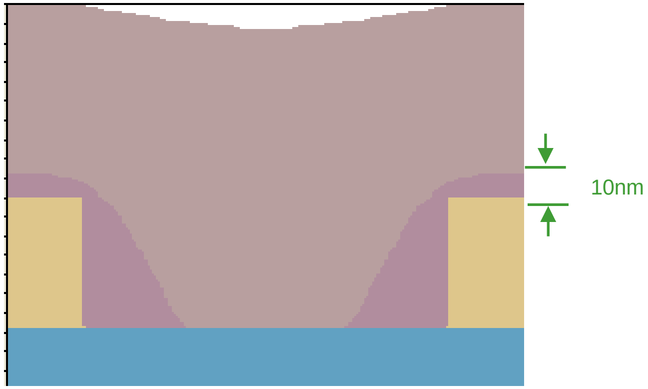
- **If the coating thickness is set such that the imported surface intersects an existing topography surface, the spincoat will be clipped by that topography**

- **In a 3D simulation, a 2D surface is assumed to extend infinitely in the perpendicular direction.**

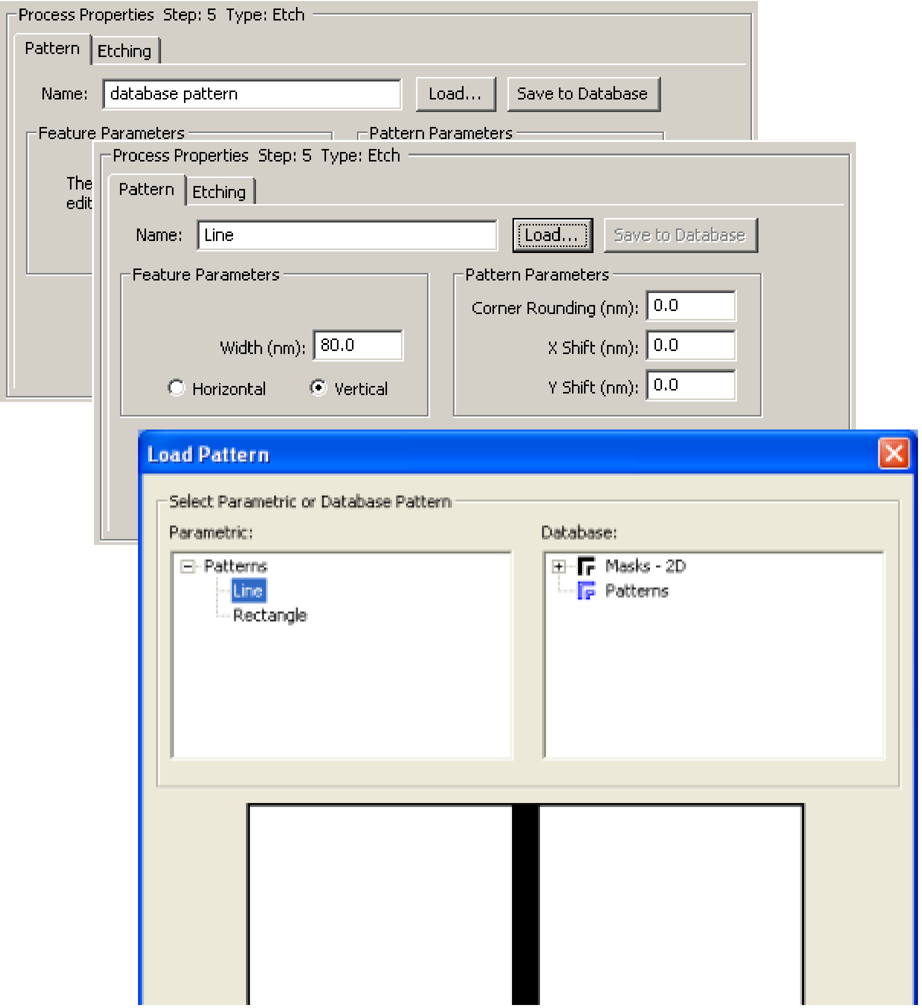
- **3D surfaces cannot be rotated since they are potentially non-symmetric.**



Step	Type	Name	Thickness (nm)
5	Resist	32nm node Double Patter...	90.000
4	Coat	Lower_bilayer_ARC	10.000
3	Etch	Line	
2	Deposit	a-Polysilicon	50.000
1	Substrate	Silicon	



Process Properties – Etch Pattern



Process Properties Step: 5 Type: Etch

Name: database pattern

Feature Parameters

Pattern Parameters

The
edit

Process Properties Step: 5 Type: Etch

Name: Line

Feature Parameters

Width (nm): 80.0

○ Horizontal ● Vertical

Pattern Parameters

Corner Rounding (nm): 0.0

X Shift (nm): 0.0

Y Shift (nm): 0.0

Parametric:

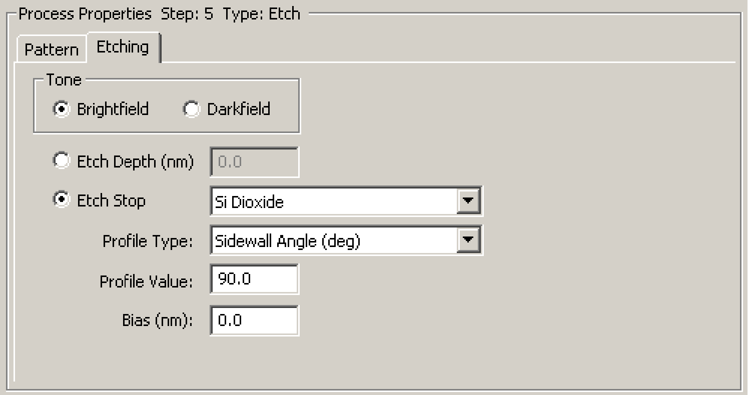
- Patterns
  - Line
  - Rectangle

Database:

- Masks - 2D
- Patterns

- Parametric or database etch patterns can be loaded
  - Parametric patterns contain editable feature parameters
  - 2D Database masks can be used as templates for etch patterns
  - Database patterns contain fixed polygon features

Process Properties – Etch Behavior



Process Properties Step: 5 Type: Etch

Tone: ● Brightfield ○ Darkfield

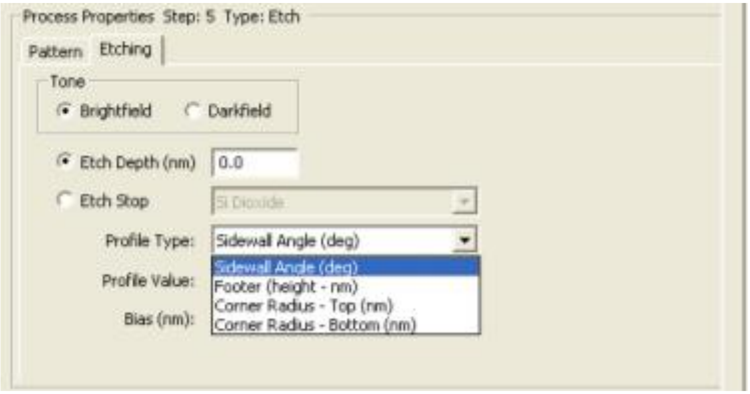
○ Etch Depth (nm): 0.0

● Etch Stop: Si Dioxide

Profile Type: Sidewall Angle (deg)

Profile Value: 90.0

Bias (nm): 0.0



Process Properties Step: 5 Type: Etch

Tone: ● Brightfield ○ Darkfield

● Etch Depth (nm): 0.0

○ Etch Stop: Si Dioxide

Profile Type: Sidewall Angle (deg)

- Sidewall Angle (deg)
- Footer (height - nm)
- Corner Radius - Top (nm)
- Corner Radius - Bottom (nm)

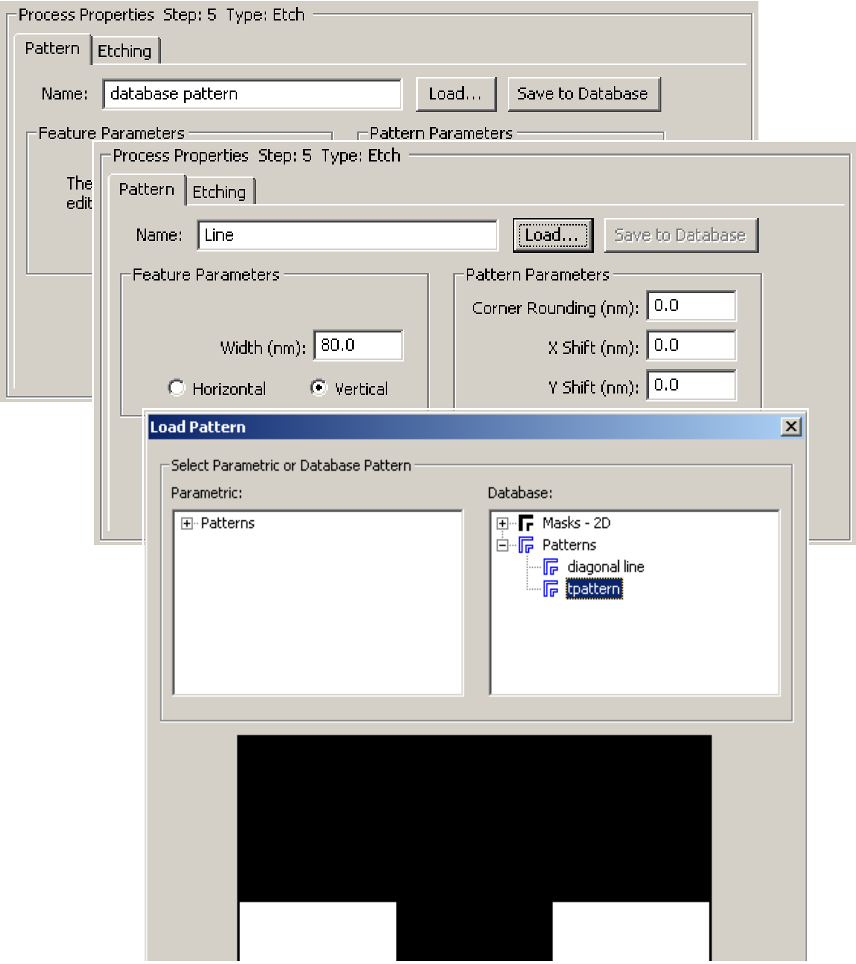
Profile Value:

Bias (nm):

- Etch tone can be specified as Brightfield or Darkfield
- Etch depth can be specified:
  - Using a fixed value
  - Using an etch stop material
- Additional profile parameters can be specified, including:
  - Profile Type
  - Profile Value
  - Bias

KLA-Tencor

Process Properties – Etch Pattern



Process Properties Step: 5 Type: Etch

Name: database pattern

Process Properties Step: 5 Type: Etch

Name: Line

Width (nm): 80.0

○ Horizontal ● Vertical

Corner Rounding (nm): 0.0

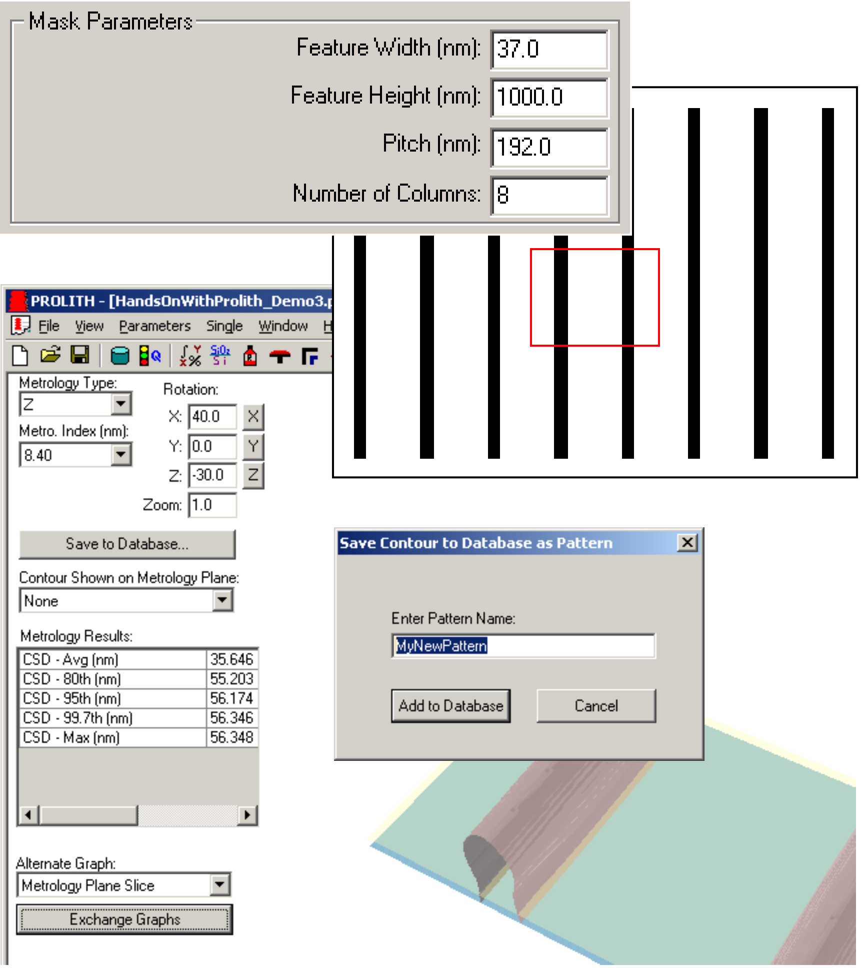
X Shift (nm): 0.0

Y Shift (nm): 0.0

- Parametric or database etch patterns can be loaded
  - Parametric patterns contain editable feature parameters
  - 2D Database masks can be used as templates for etch patterns
  - Database patterns contain fixed polygon features

Create Etch Pattern - Example

- Load a 2D mask
- Setup the parameters to create the desired printed CD
    - Adjust feature bias
    - Set exposure energy
    - Set a 2D simulation region
- Run a resist profile
- Select Z slice at desired profile height
- Click Save to Database and enter a name for the saved pattern



Mask Parameters

Feature Width (nm): 37.0

Feature Height (nm): 1000.0

Pitch (nm): 192.0

Number of Columns: 8

PROLITH - [HandsOnWithProlith_Demo3.p

Metrology Type: Z

Metro. Index (nm): 8.40

Rotation:

X: 40.0

Y: 0.0

Z: -30.0

Zoom: 1.0

Contour Shown on Metrology Plane: None

Metrology Results:

CSD - Avg (nm)	35.646
CSD - 80th (nm)	55.203
CSD - 95th (nm)	56.174
CSD - 99.7th (nm)	56.346
CSD - Max (nm)	56.348

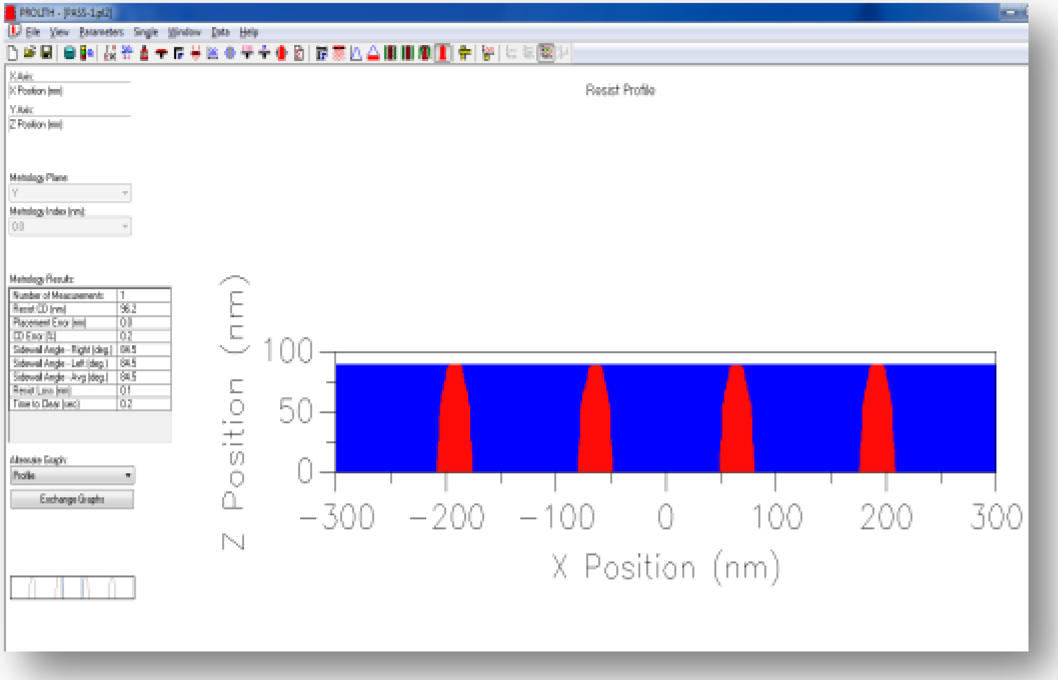
Alternate Graph: Metrology Plane Slice

Save Contour to Database as Pattern

Enter Pattern Name: MyNewPattern

Import topography from PROLITH Simulation LLE Process 1st Pass Simulation

- Run first pass lithography as a standard PROLITH simulation with topography off.
- Save the PL2 after running the simulation through resist profile.
- 2D and 3D simulations as supported.



X Axis: X Position (nm)

Y Axis: Z Position (nm)

Metrology Plane: Y

Metrology Index (nm): 0.0

Metrology Results:

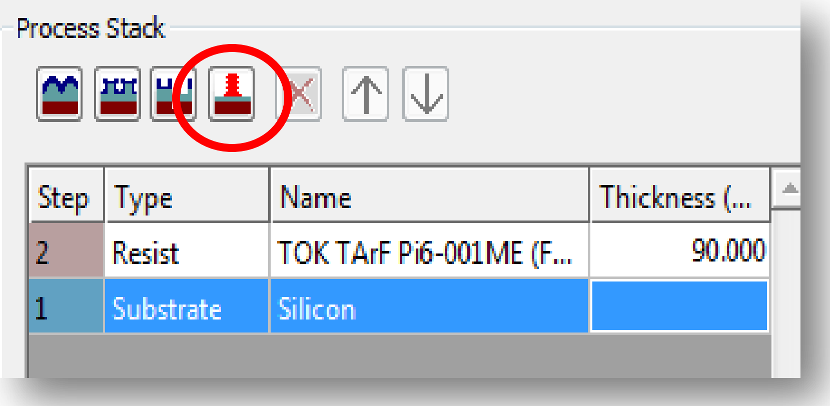
Number of Measurements	1
Resist CD (nm)	96.2
Placement Error (nm)	0.0
CD Error (%)	0.2
Sidewall Angle - Right (deg.)	84.5
Sidewall Angle - Left (deg.)	84.5
Sidewall Angle - Avg (deg.)	84.5
Resist Loss (nm)	0.1
Time to Clear (sec)	0.2

Alternate Graph: Profile

LLE Process 2nd Pass Simulation

Note: There are many business rules. Please use online help by pressing F1 for more information about business rules.

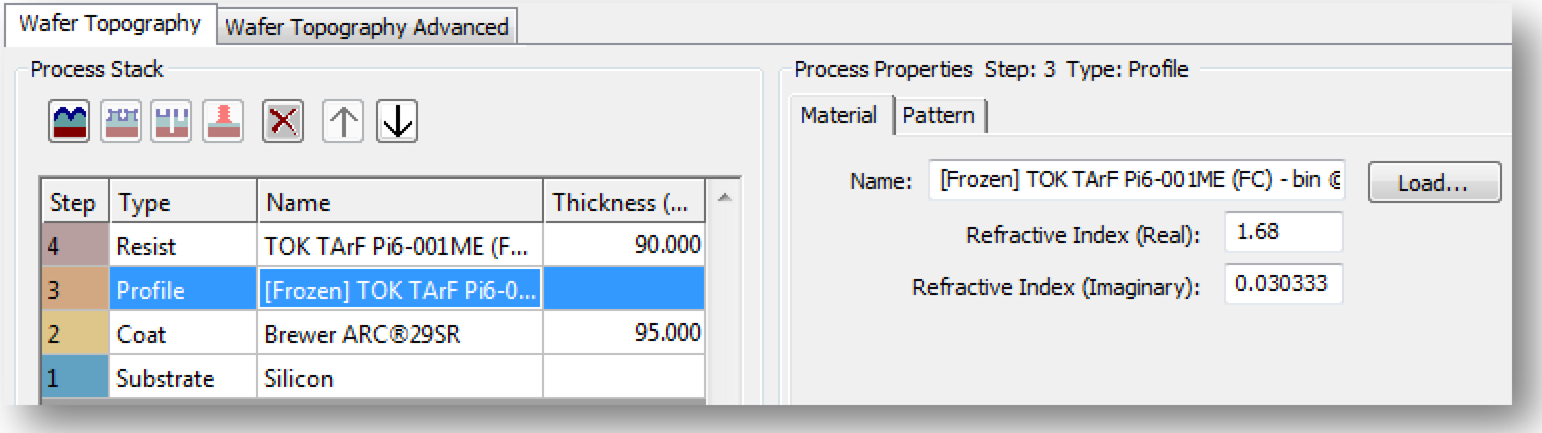
- For Pass 2 use a PL2 with topography active
- Use import lithography stack button on the wafer processes page to bring in the resist features from the saved Pass 1 simulation.



Step	Type	Name	Thickness (...
2	Resist	TOK TArF Pi6-001ME (F...	90.000
1	Substrate	Silicon	

- The Pass 1 resist is imported as a topography material with the n & k of the resist of the previous simulation.
- The 1st Pass PL2 must be created with the same version of PROLITH as is being used for the 2nd pass and contain the simulation data for the final resist profile.

LLE Process 2nd Pass Simulation



Process Properties Step: 3 Type: Profile

Step	Type	Name	Thickness (...
4	Resist	TOK TArF Pi6-001ME (F...	90.000
3	Profile	[Frozen] TOK TArF Pi6-0...	
2	Coat	Brewer ARC®29SR	95.000
1	Substrate	Silicon	

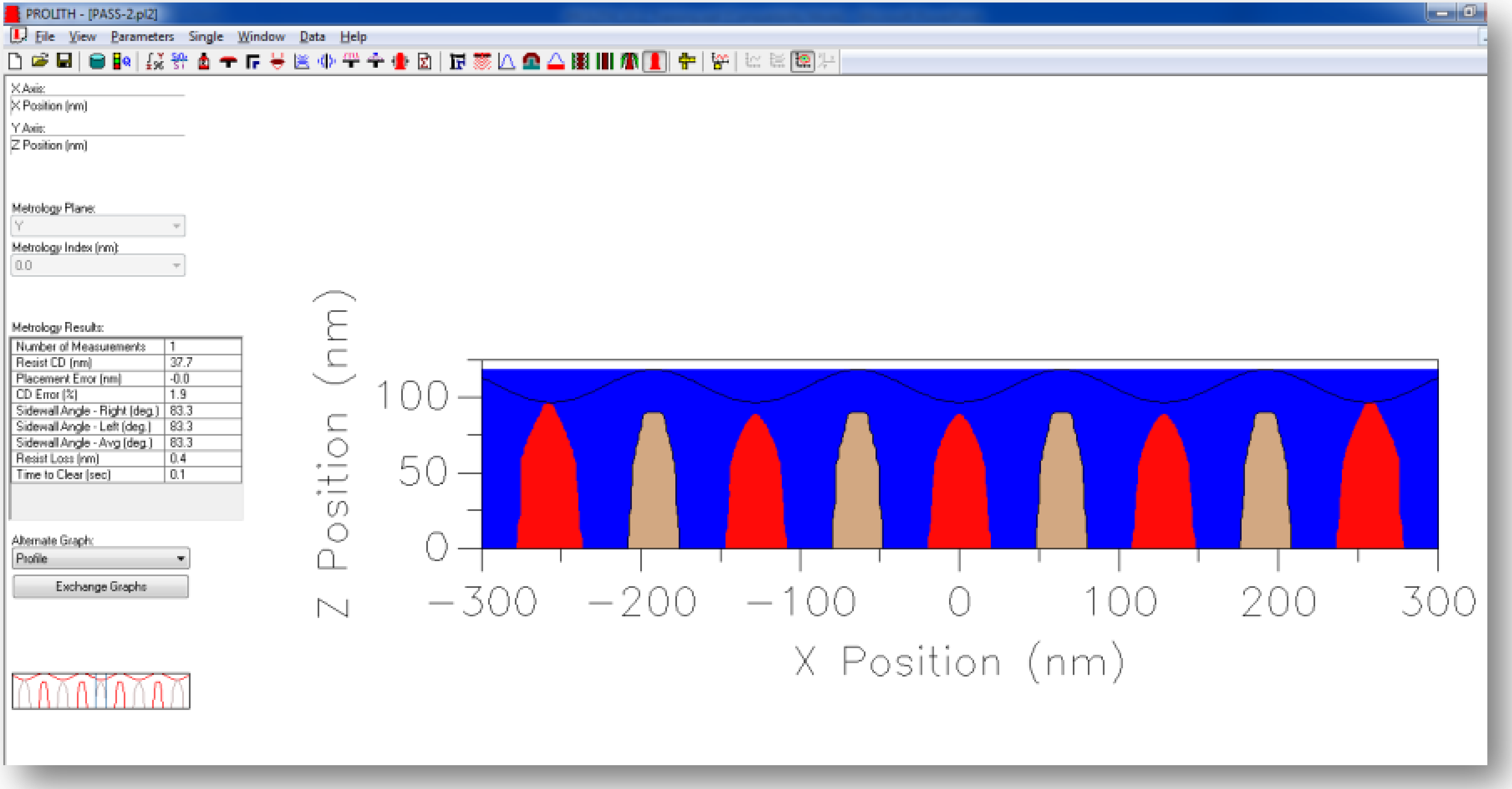
Name: [Frozen] TOK TArF Pi6-001ME (FC) - bin

Refractive Index (Real): 1.68

Refractive Index (Imaginary): 0.030333

- Once the lithographic stack is imported the user can:
  - Change the n&k of the 1st pass resist
  - Alter the thickness and n&k of the BARC layer
  - Spin coat 2nd resist over the imported frozen resist profile
  - Add substrate contamination to the 2nd pass simulation
- NOTE: In PROLITH X3.2 the imported resist is truly frozen, i.e. is completely inert.

LLE Process 2nd Pass Simulation



X Axis:
X Position (nm)

Y Axis:
Z Position (nm)

Metrology Plane:
Y

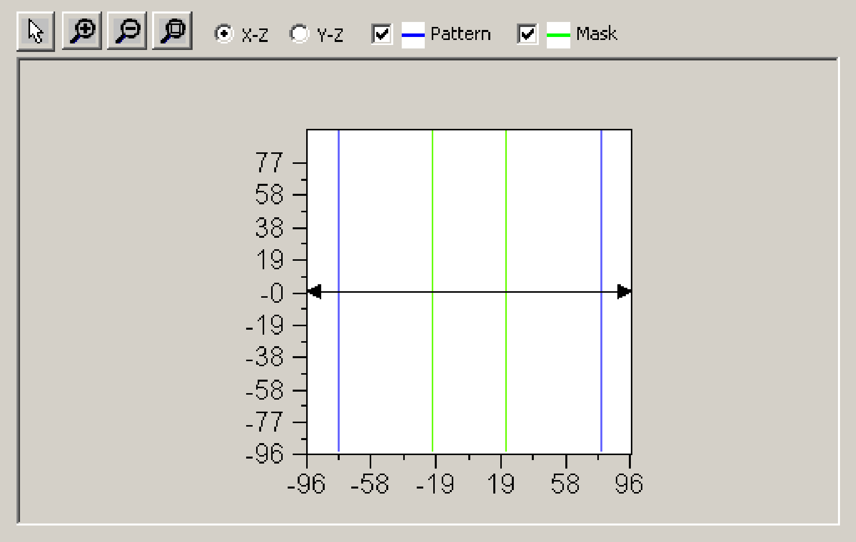
Metrology Index (nm):
0.0

Metrology Results:

Number of Measurements	1
Resist CD (nm)	37.7
Placement Error (nm)	-0.0
CD Error (%)	1.9
Sidewall Angle - Right (deg.)	83.3
Sidewall Angle - Left (deg.)	83.3
Sidewall Angle - Avg (deg.)	83.3
Resist Loss (nm)	0.4
Time to Clear (sec)	0.1

Alternate Graph:
Profile

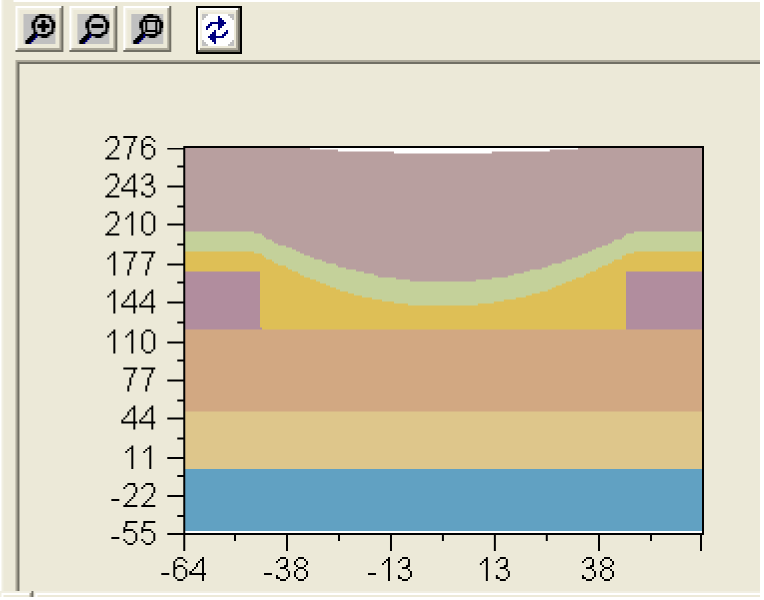
Mask Image



Green = Mask Pattern
Blue = Topography Pattern

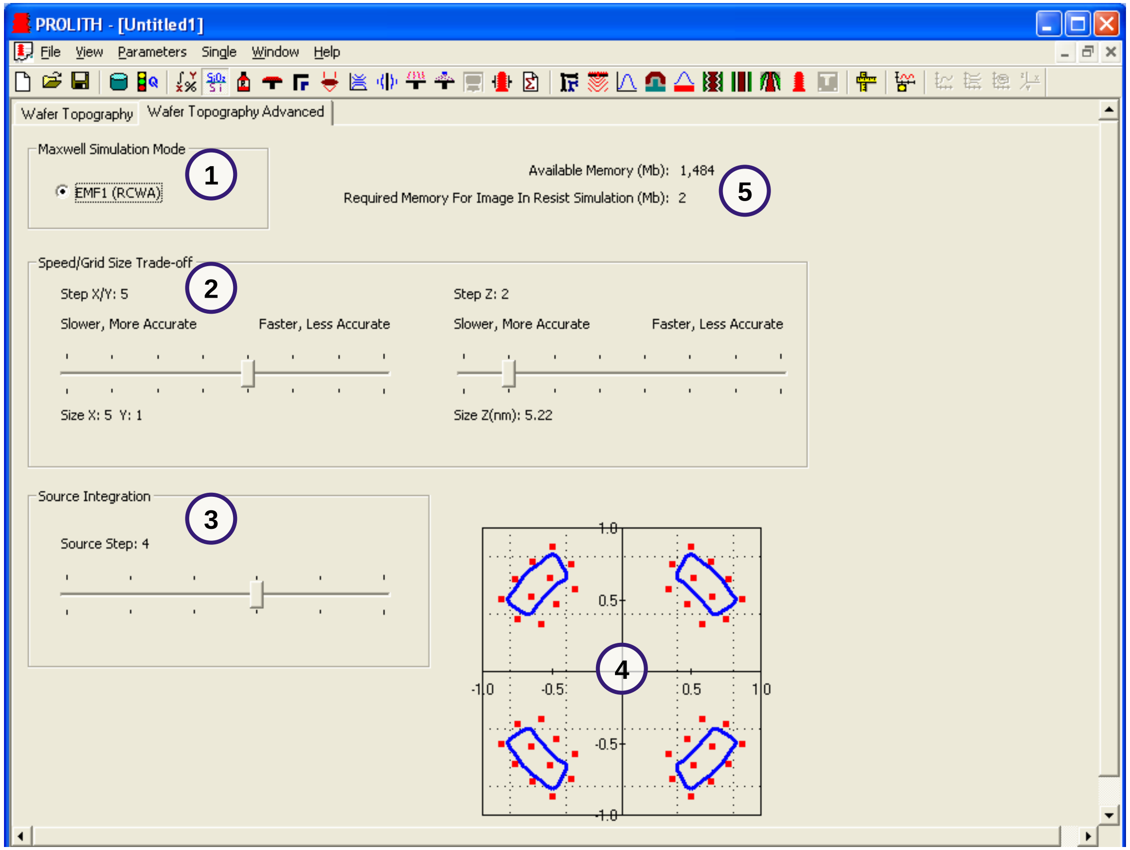
- Zoom in/out on a section of the image using the + and - magnifying glass buttons
- Turn on/off display of the etch pattern or mask using the checkboxes
- Change the cross-section shown in the wafer stack image
  - Select horizontal or vertical
  - Use the arrow selection tool to move the cross-section
  - Click the **Update** button in the process stack image to refresh the wafer stack image

Wafer Stack Image



- Image will not be shown until update is selected (unless a single run has been executed through the wafer topography output view)
- Image is for cutline shown in Mask Image
- Zoom in/out on a section of the image using the + and - magnifying glass buttons
- Update the process stack image after making changes to the steps
- Thickness information is now output on the 'wafer topography' output view.

Wafer Topography Advanced



Maxwell Simulation Mode

● EMF1 (RCWA)

Available Memory (Mb): 1,484

Required Memory For Image In Resist Simulation (Mb): 2

Speed/Grid Size Trade-off

Step X/Y: 5

Size X: 5 Y: 1

Step Z: 2

Size Z(nm): 5.22

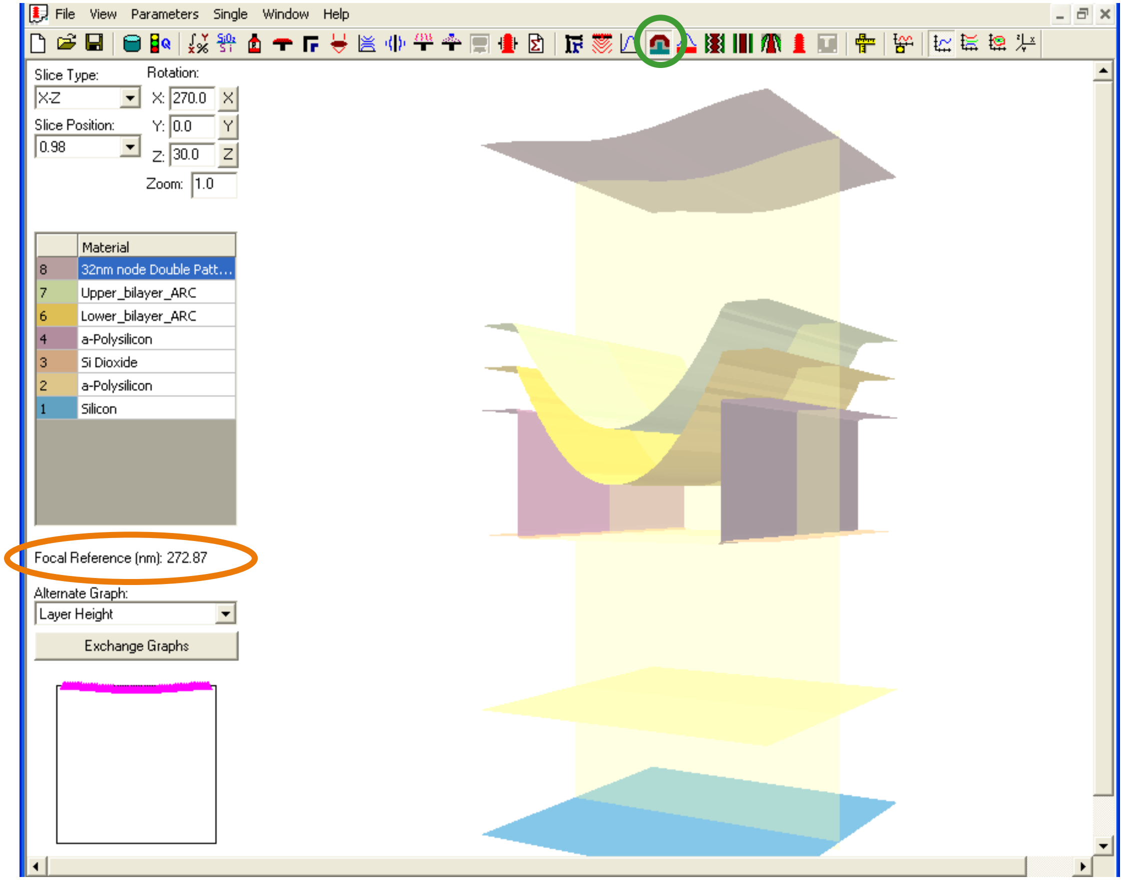
Source Integration

Source Step: 4

1. Maxwell Simulation Mode (only RCWA at this time)
2. Speed Factor/Grid settings (recommend 5 for 3D topography simulations)
3. Source Integration (recommend 3 or 4)
4. Source sample plan
5. Memory estimates

Wafer Topography Output View

- New ***'wafer topography output'*** view present when wafer topography is active.
- Topography which corresponds to the 'mask' region is displayed.
  - For 3D simulations the defined mask region is displayed.
  - For 2D simulations a square region is shown with both sides equal to the mask pitch.
- The **height of the focal reference plane above the substrate surface** is displayed on this page



Slice Type: X-Z

Slice Position: 0.98

Rotation:
X: 270.0
Y: 0.0
Z: 30.0
Zoom: 1.0

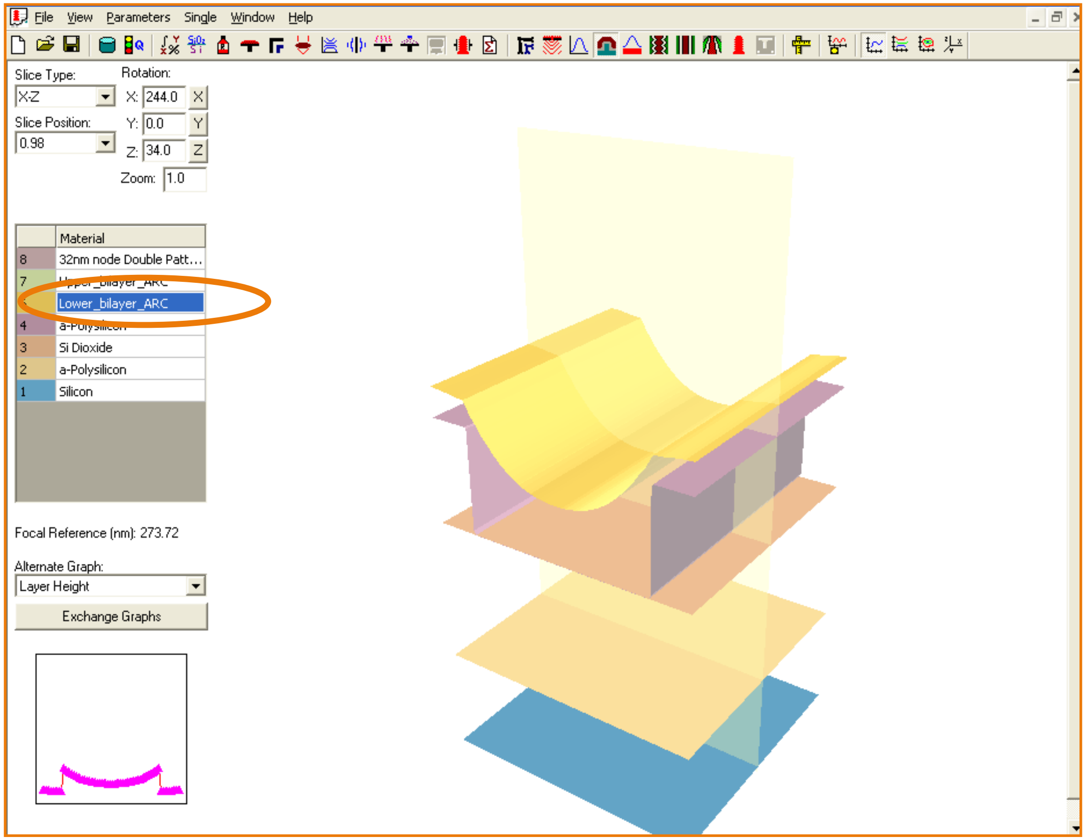
	Material
8	32nm node Double Patt...
7	Upper_bilayer_ARC
6	Lower_bilayer_ARC
4	a-Polysilicon
3	Si Dioxide
2	a-Polysilicon
1	Silicon

Focal Reference (nm): 272.87

Alternate Graph: Layer Height

Wafer Topography Output View

- The 3D image can be rotated using the mouse when the ***'shift'*** key is held
- When the user **selects a material in the layer grid**:
  - Layers above the selected material are no longer displayed
  - The alternate graph thickness information for that layer is displayed.
- In the alternate graph area thickness and height information for the selected layer is displayed



Slice Type: X-Z

Rotation:
X: 244.0
Y: 0.0
Z: 34.0

Slice Position: 0.98

Zoom: 1.0

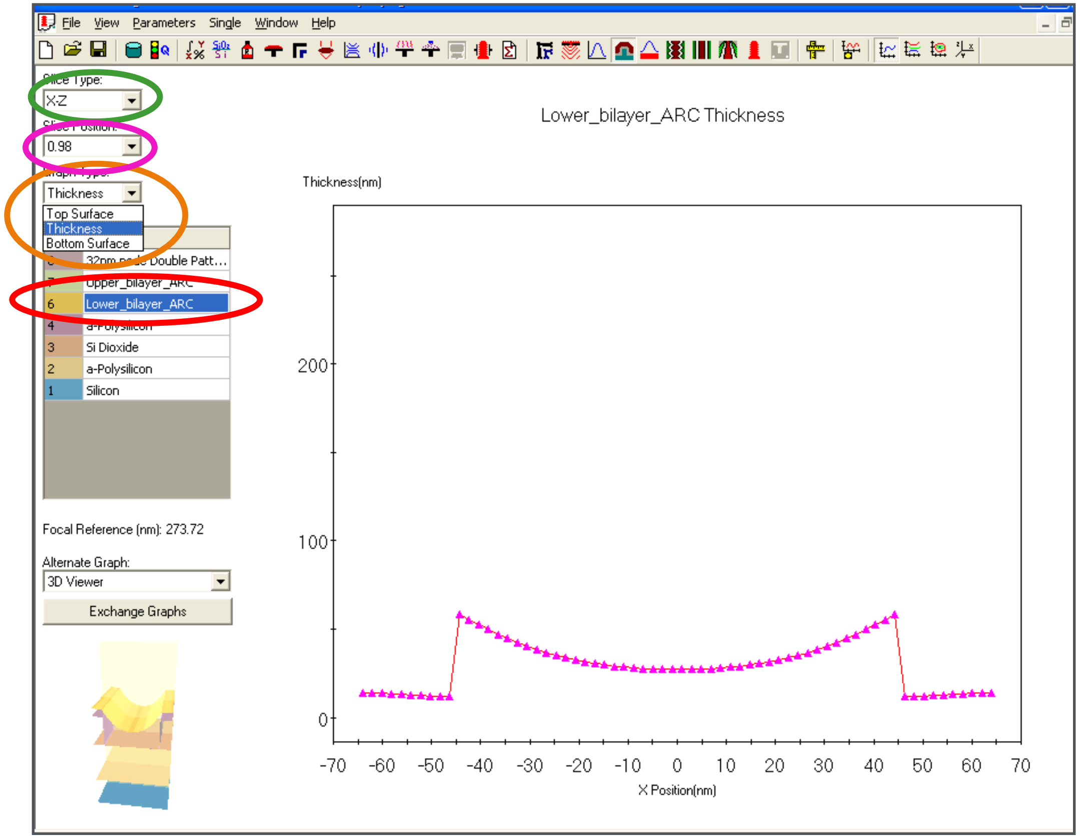
	Material
8	32nm node Double Patt…
7	Upper_bilayer_ARC
	Lower_bilayer_ARC
4	a-Polysilicon
3	Si Dioxide
2	a-Polysilicon
1	Silicon

Focal Reference (nm): 273.72

Alternate Graph: Layer Height

Wafer Topography Output View – Alternate graphs

- The alternate graph can display either *‘cross section’* (the same as on the topography set-up screen) or ***‘layer height’*** information.
- When ***‘layer height’*** is selected a line plot of either **thickness, top surface height or bottom surface height** can be shown for the **‘active’ material**.
- The **direction of the plane can be toggled from X to Y**.
- The **position of sample plane can be moved across the mask region**.



Slice Type: X-Z

Slice Position: 0.98

Graph Type: Thickness

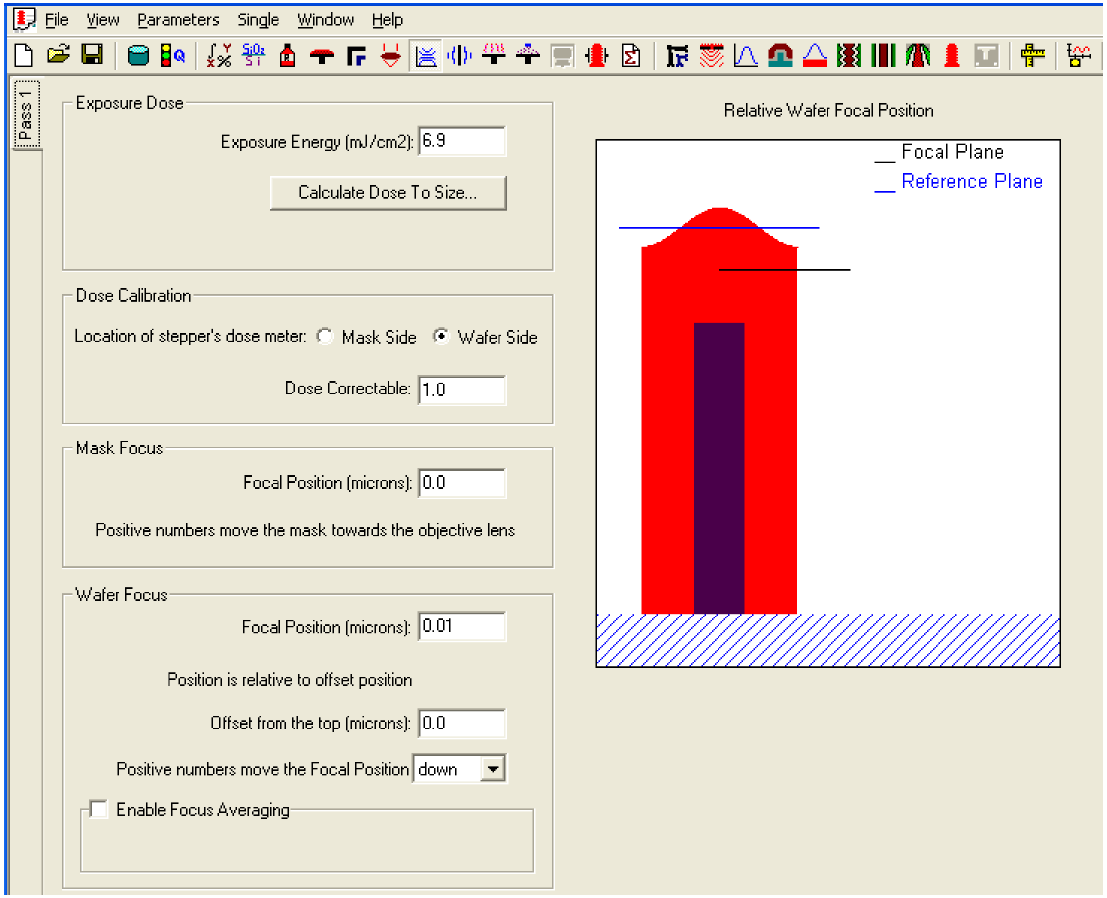
	32nm node Double Patt…
7	Upper_bilayer_ARC
6	Lower_bilayer_ARC
4	a-Polysilicon
3	Si Dioxide
2	a-Polysilicon
1	Silicon

Focal Reference (nm): 273.72

Alternate Graph: 3D Viewer

The Focal Reference Plane

- **Problem:** Where should focus offset be anchored to for complex topography?
- After consultation with scanner vendors the final solutions is that ***the reference focal plane is the average top surface height of the stack***.
- An offset can be applied.
- The plane is recalculated dynamically as topography and coat/deposition processes change.



Exposure Dose

Exposure Energy (mJ/cm2): 6.9

Dose Calibration

Location of stepper's dose meter: ○ Mask Side ● Wafer Side

Dose Correctable: 1.0

Mask Focus

Focal Position (microns): 0.0

Positive numbers move the mask towards the objective lens

Wafer Focus

Focal Position (microns): 0.01

Position is relative to offset position

Offset from the top (microns): 0.0

Positive numbers move the Focal Position down

☐ Enable Focus Averaging

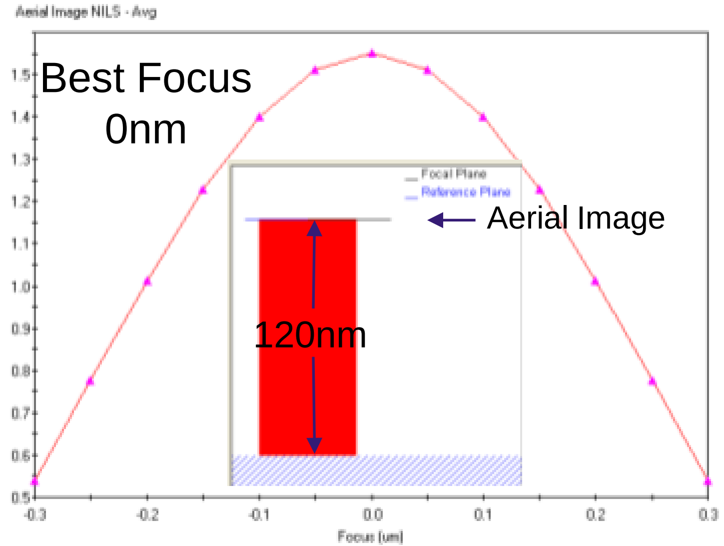
Aerial Image

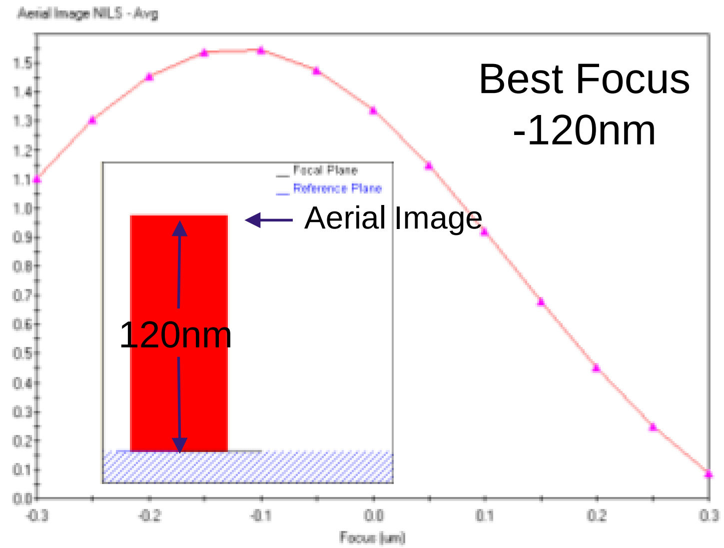
- Aerial image is the image of the mask projected into the imaging media without the film stack present. Although the aerial image doesn’t really exist in real lithographic imaging, it is easy to calculate and is a convenient proxy for the final resist image.
- The un-aberrated aerial image should be symmetrical round focus equals zero.
- In PROLITH v 12 and earlier, the aerial image was measured at a special plane at the top surface of the resist film.
  - Thus the expected behavior is observed when the ‘wafer focus position’ is determined by the ‘resist top’.
  - Due to the piece-wise evolution of PROLITH, the expected behavior is not observed when other ‘wafer focus position’ references are chosen, or a top-coat is employed. In such cases a stack dependent focus offset is introduced between the aerial image best focus and the zero focus position.

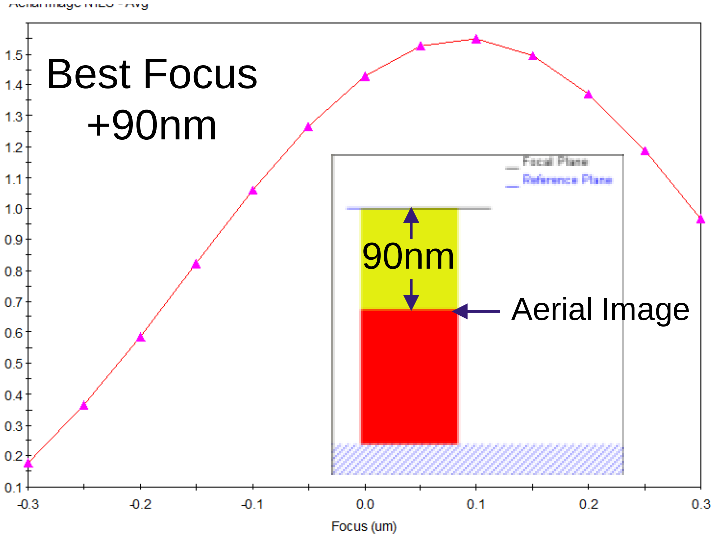
Aerial Image

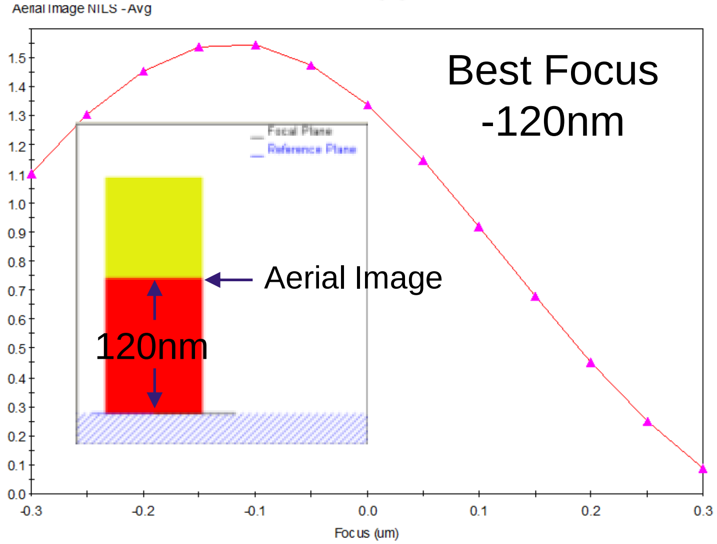
- The introduction of general wafer topography necessitates a change in the special aerial image plane as the top surface of the resist may not be planar in all cases.
- The special aerial image is now sampled in the defined ‘focal reference plane’.
  - This new plane is utilized for all simulations, not just wafer topography simulation
  - An un-aberrated aerial image will always be at ‘best focus’ when the focus value is at zero, no matter which position wafer focus is measured against.
  - The aerial image results will not change when the stack is altered (i.e., it is uneffected by changes to top coat or resist thickness).

Version 12 Examples: NILS versus Focus

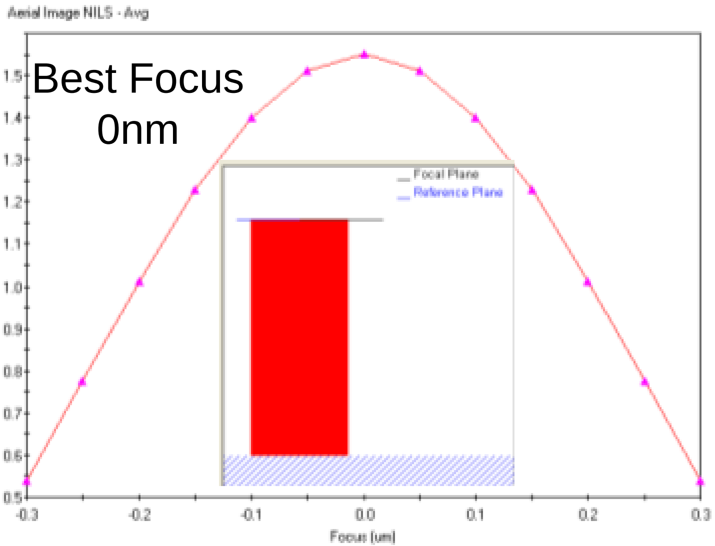




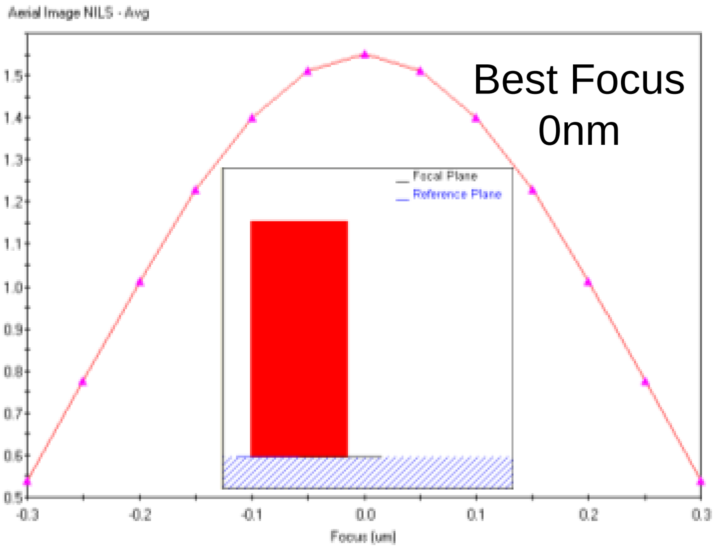




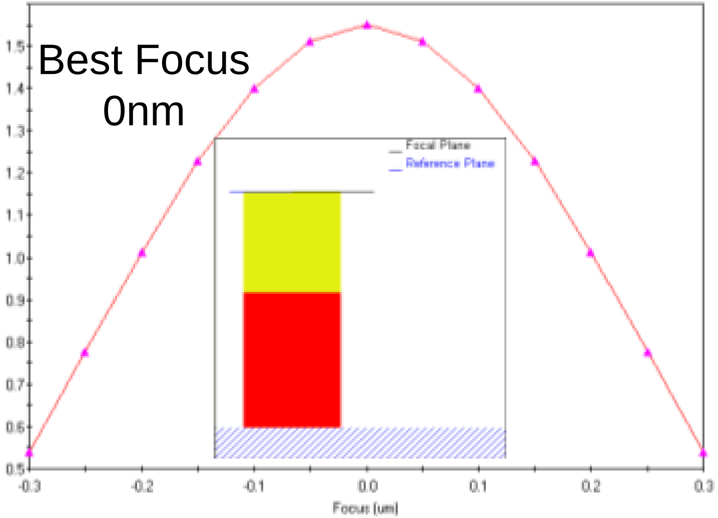
Version X3 Examples: NILS versus Focus



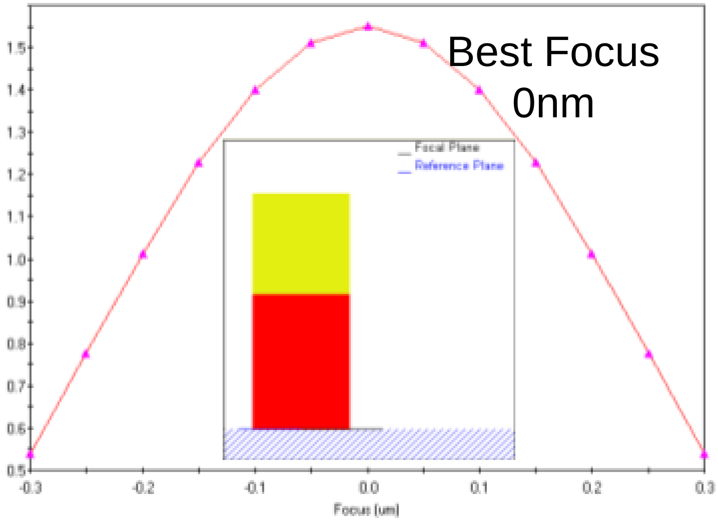
Best Focus
0nm



Best Focus
0nm



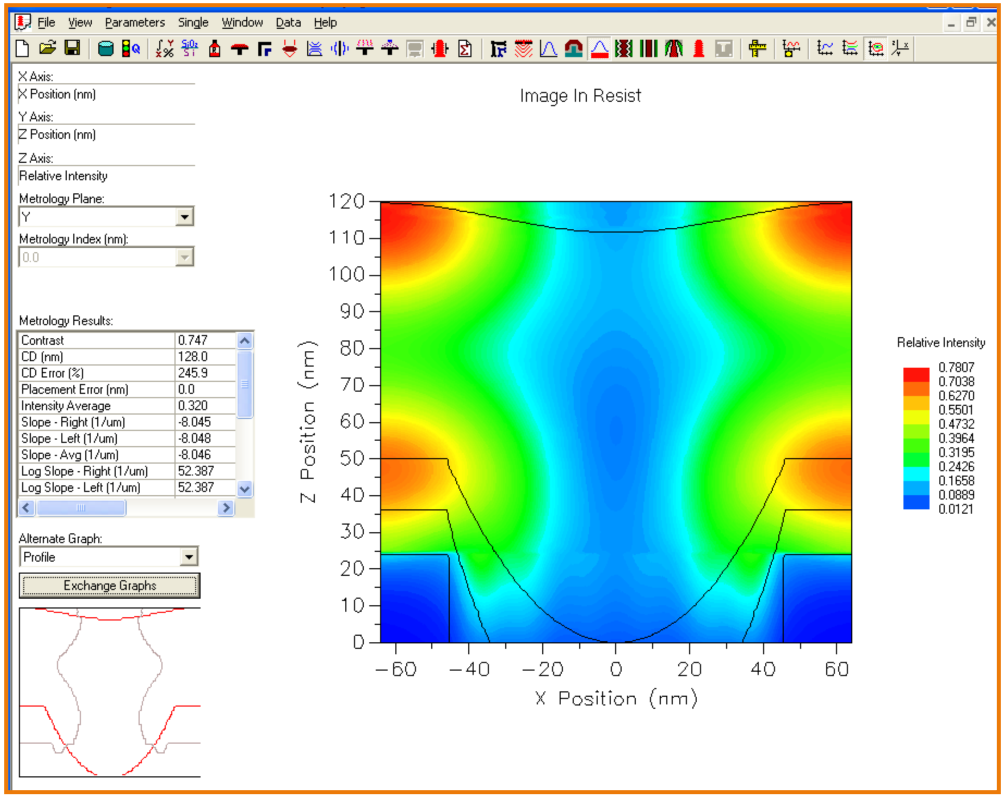
Best Focus
0nm



Best Focus
0nm

‘Image in resist’ Output – Main View

- The ‘image in resist’ view shows the intensity in the stack for all regions that are co-planar with the resist region for the active metrology plane.
- The displayed region extends from the lowest point in the resist sim region (Z=0) to the highest point
- All interfaces within the region are shown as black lines
- All metrics for this view are calculated using the standard PROLITH methods.



X Axis: X Position (nm)

Y Axis: Z Position (nm)

Z Axis: Relative Intensity

Metrology Plane: Y

Metrology Index (nm): 0.0

Metrology Results:

Contrast	0.747
CD (nm)	128.0
CD Error (%)	245.9
Placement Error (nm)	0.0
Intensity Average	0.320
Slope - Right (1/um)	-8.045
Slope - Left (1/um)	-8.048
Slope - Avg (1/um)	-8.046
Log Slope - Right (1/um)	52.387
Log Slope - Left (1/um)	52.387

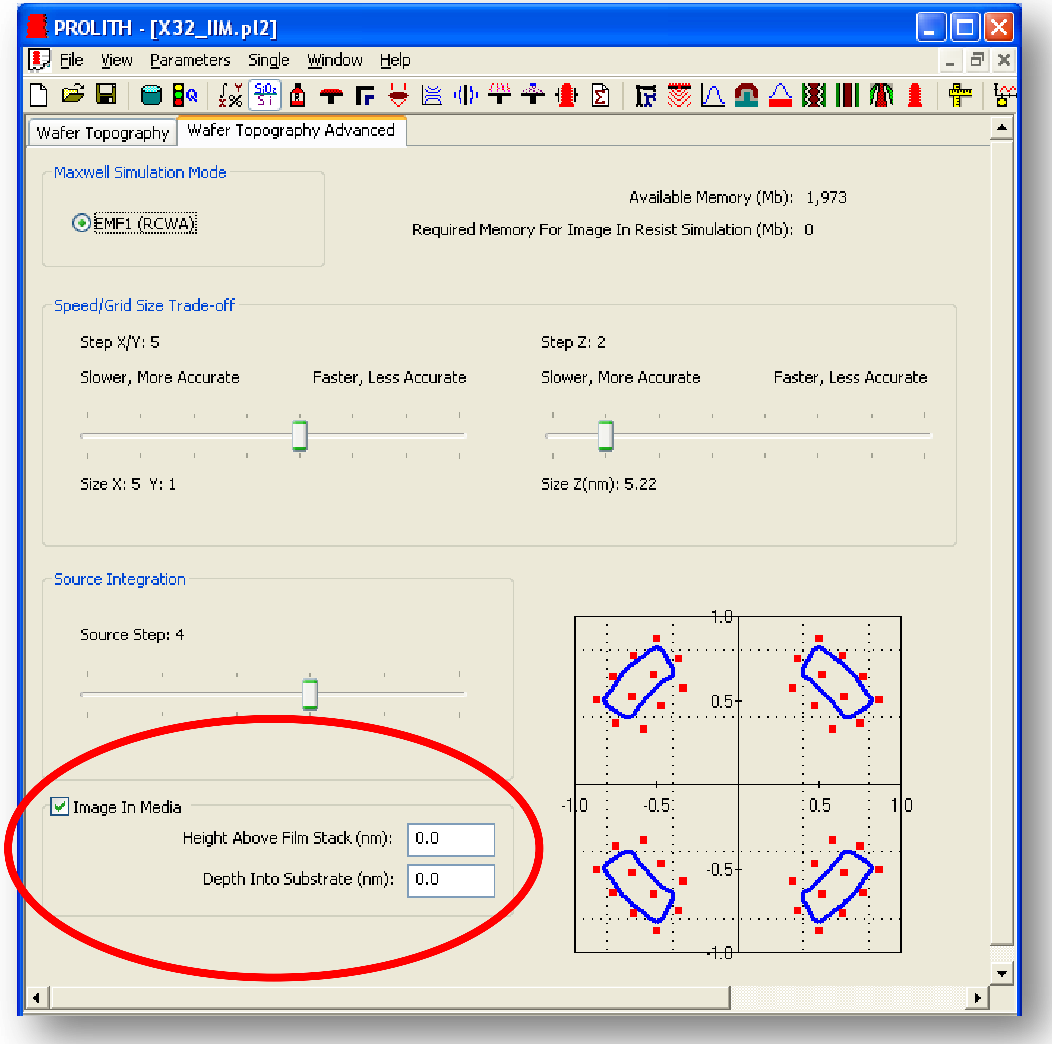
Alternate Graph: Profile

Image in Media

- In X3.0 and X3.1 PROLITH only displays the light intensity for the resist region and materials in the same plane.

- In PROLITH X3.2, the user can opt to display the intensity through the full process stack.

- Note: This requires additional memory and increases computation time.



Maxwell Simulation Mode

● EMF1 (RCWA)

Available Memory (Mb): 1,973

Required Memory For Image In Resist Simulation (Mb): 0

Speed/Grid Size Trade-off

Step X/Y: 5

Step Z: 2

Size X: 5 Y: 1

Size Z(nm): 5.22

Source Integration

Source Step: 4

☑ Image In Media

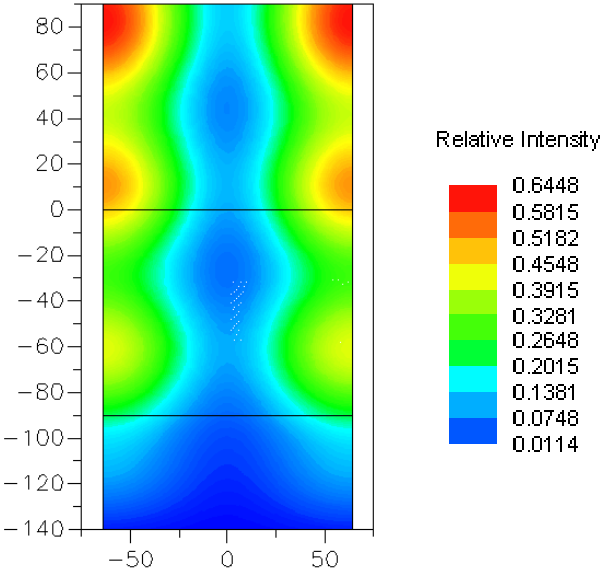
Height Above Film Stack (nm): 0.0

Depth Into Substrate (nm): 0.0

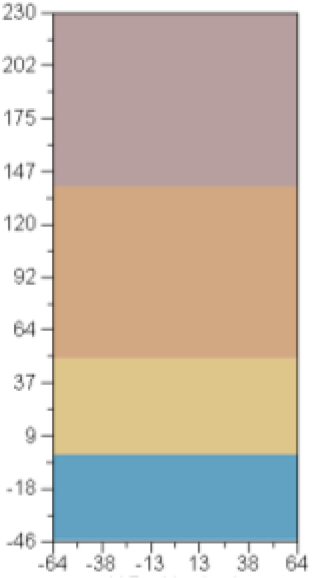
Image in Media

- PROLITH X3.0 (3.1) could be tricked into providing image in the stack but was slow. Image in topcoat was not possible.
- New option delivers same result but in significantly less time.

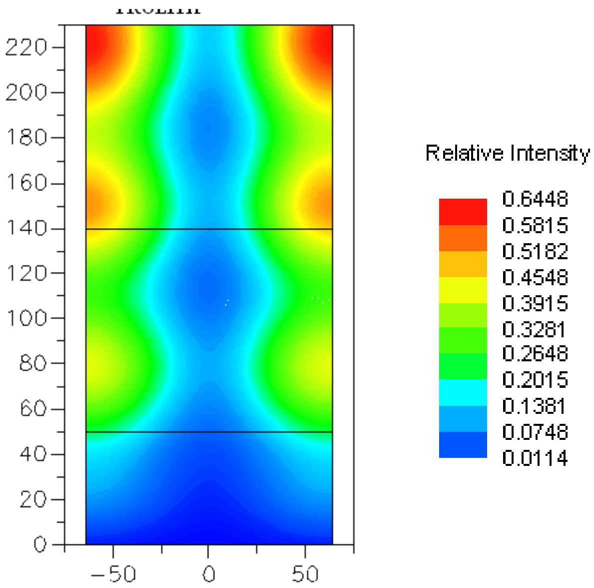
X3.2 IIM



4 sec



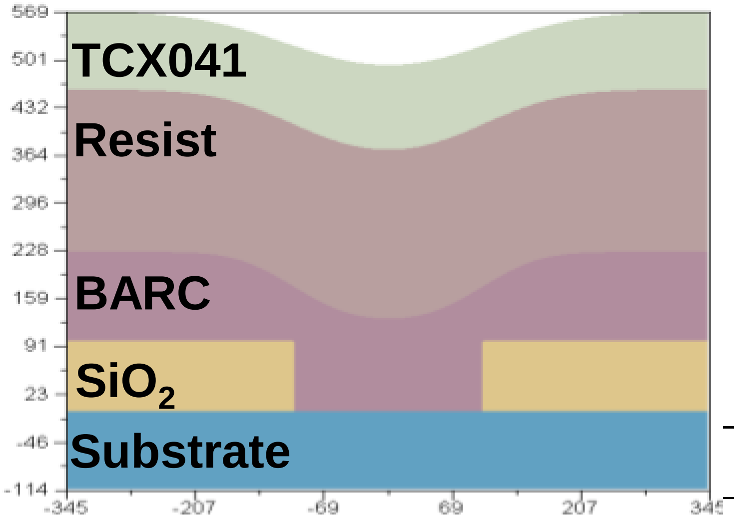
X3.0 with ‘trick’

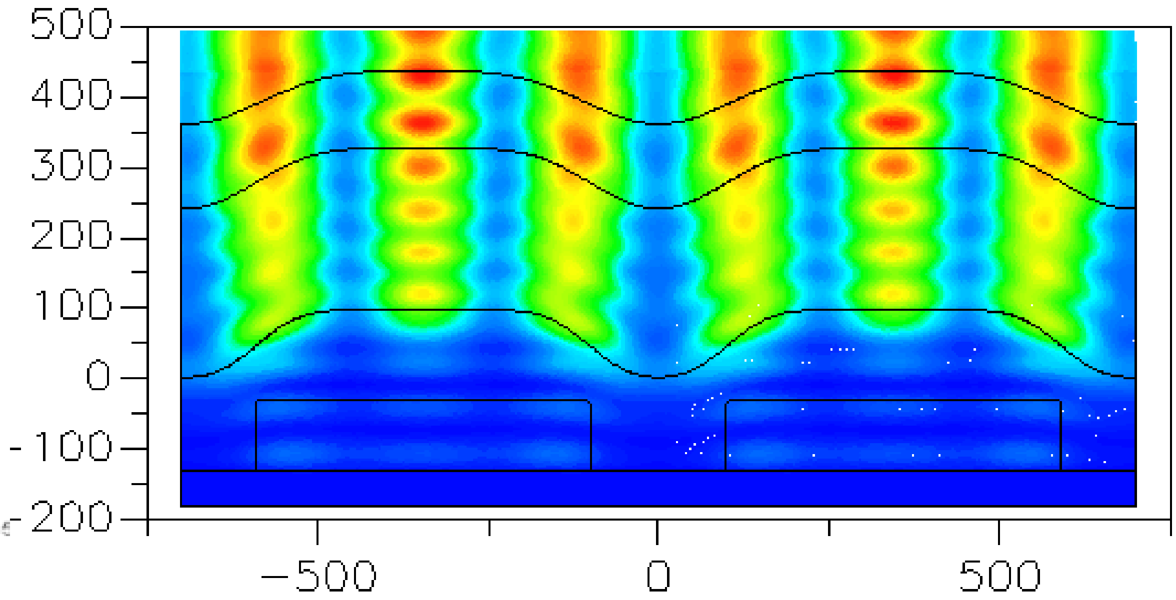


5 min 32 sec

Image In Media

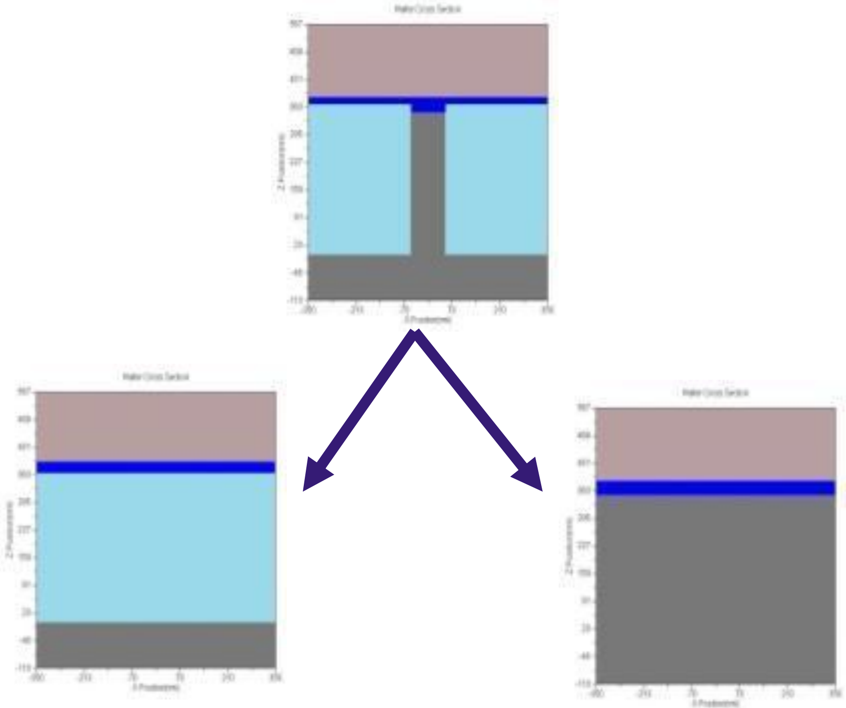
- Can now use etch in the stack (instead of being used to induce ‘trick’)
- Now possible to get the image intensity in top coat
- User can optionally extend the image intensity into the substrate or superstrate (typically air or water).





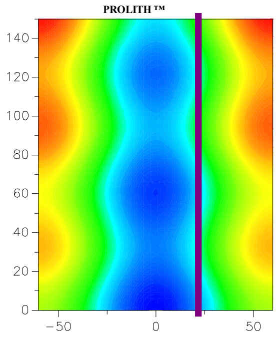
Reflectivity Options with PROLITH

Planar film stacks

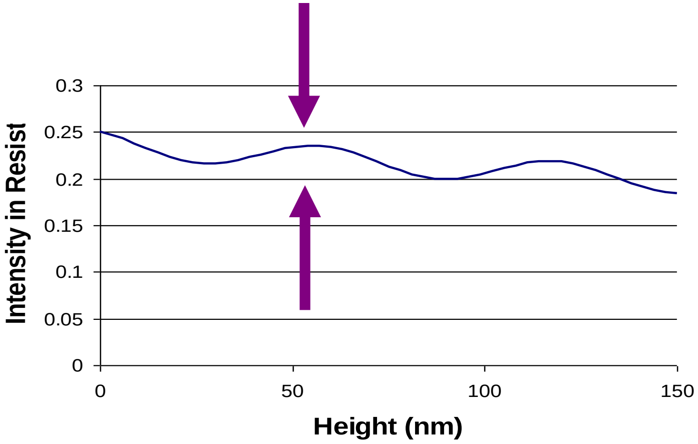


- Split topography into regions that can be approximated with planar film stacks.
- This is a global metric, so it should be used for general solutions.
- Pros: Calculate reflectivity as usual.
- Cons: What if topography is small and notching/scattering is important?

Standing wave amplitude

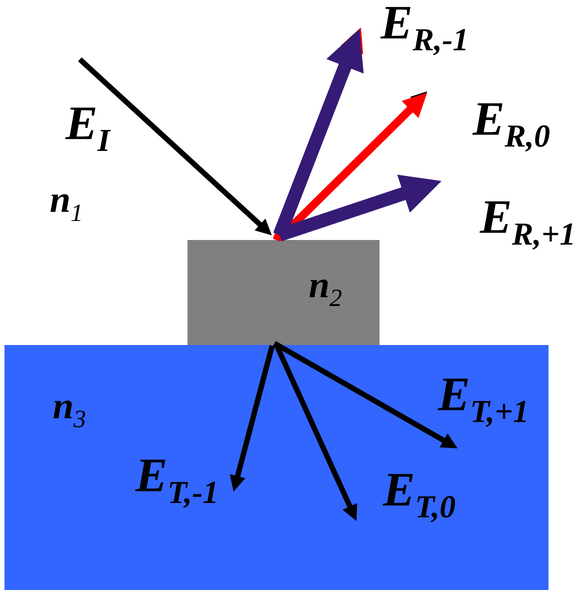


Along the feature edge, intensity looks like a swing curve.



- Calculate "swing ratio" and report as Standing Wave Amplitude (SWA)
- This is a localized metric, so it should be used for specific solutions for critical features.
- Pros: Easy to understand. Can be calculated locally.
- Cons: For thin films, may not get full "swing", so SWA may not be accurate. Also, for dark-field, signal-to-noise in dark regions is bad.

Reflectivity with Topography – New Metric Reflected Diffraction Efficiencies



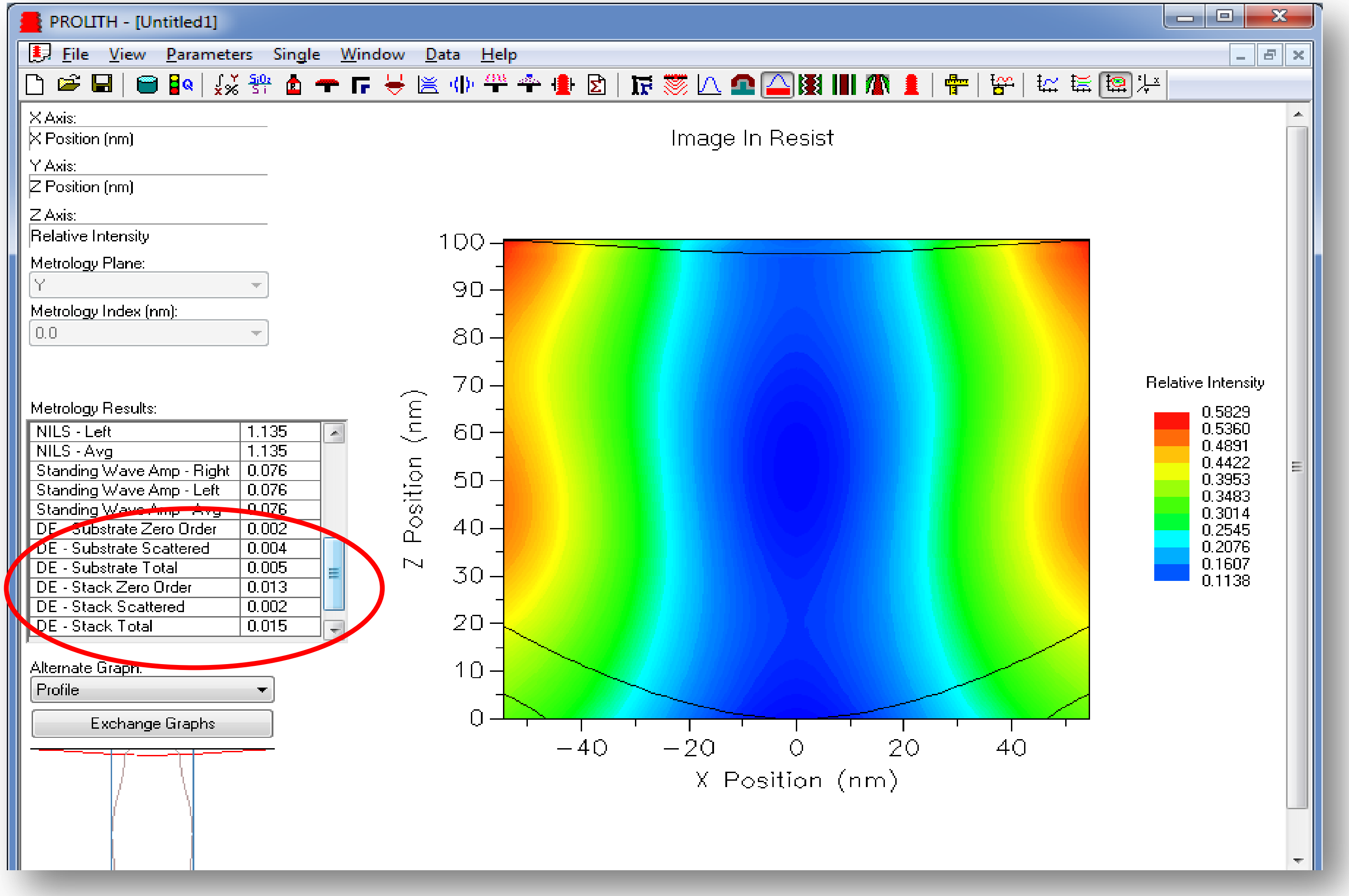
$$\text{Zero Order} = \mathcal{R}_0$$

$$\text{All} = \sum \mathcal{R}_i$$

Scattered = All – Zero Order

- Resist & Substrate reflectivity
  - Zero order, Scattered, & All
- A **global** metric, so good for **general** solutions
- Zero Order Reflection Efficiency is what is reported in scatterometry.
- All Reflection Efficiencies is total energy reflected off grating.

New Reflectivity Outputs - Image in Resist



X Axis:
X Position (nm)

Y Axis:
Z Position (nm)

Z Axis:
Relative Intensity

Metrology Plane:
Y

Metrology Index (nm):
0.0

Metrology Results:

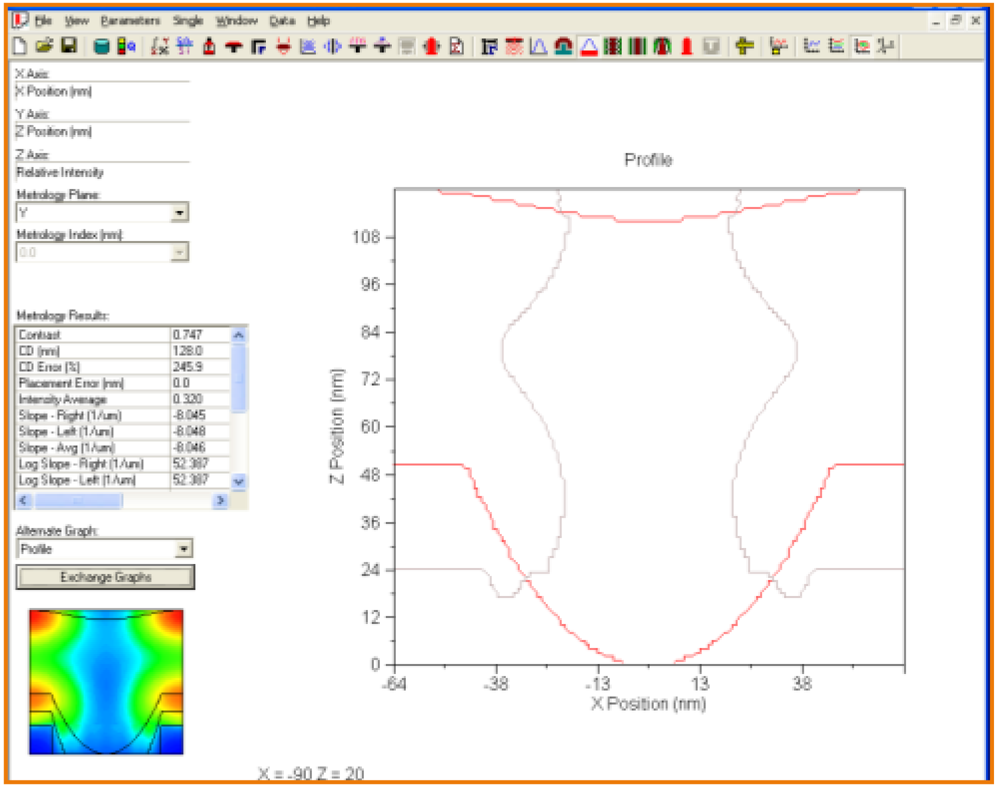
NILS - Left	1.135
NILS - Avg	1.135
Standing Wave Amp - Right	0.076
Standing Wave Amp - Left	0.076
Standing Wave Amp - Avg	0.076
DE - Substrate Zero Order	0.002
DE - Substrate Scattered	0.004
DE - Substrate Total	0.005
DE - Stack Zero Order	0.013
DE - Stack Scattered	0.002
DE - Stack Total	0.015

Alternate Graph:
Profile

Reference: Reflectivity metrics for optimization of anti-reflection coatings on wafers with topography. Mark D. Smith, Trey Graves, Stewart Robertson, and John Biafore, SPIE 2010. SPIE, 7639, 763935

‘Image in resist’ Output – Alternate Profile View

- When exchange graph is toggled to the profile view, the contour of the resist image intensity (defined on the metrology page) is displayed for the active metrology plane.
- The contour is displayed in grey.
- The upper and lower interfaces of the resist are displayed as red contours
- When the contour data is exported (using either the “data menu” or <ctrl> and mouse drag, only the resist image intensity contour values are included.



X Axis: X Position (nm)

Y Axis: Z Position (nm)

Z Axis: Relative Intensity

Metrology Plane: Y

Metrology Index (nm): 0.0

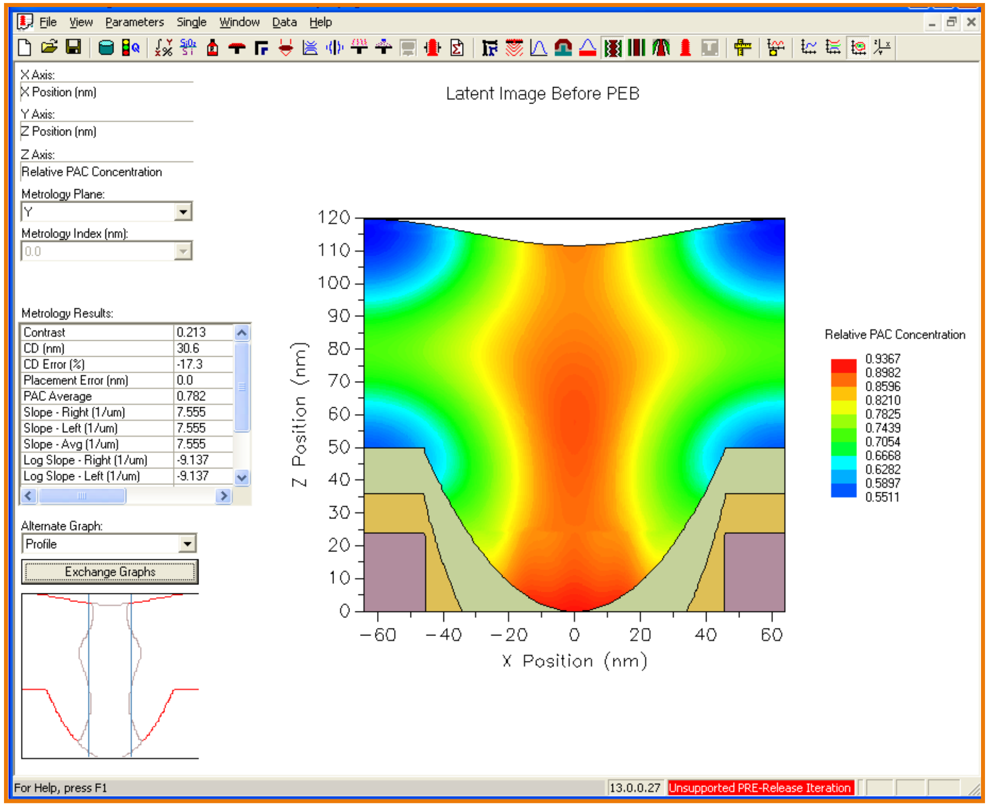
Metrology Results:

Contrast	0.747
CD (nm)	128.0
CD Error (%)	245.9
Placement Error (nm)	0.0
Intensity Average	0.320
Slope - Right (1/um)	-8.045
Slope - Left (1/um)	-8.048
Slope - Avg (1/um)	-8.046
Log Slope - Right (1/um)	52.387
Log Slope - Left (1/um)	52.387

Alternate Graph: Profile

‘Latent Image before PEB’ Output – Main View

- The ‘Latent image before PEB’ view shows the relative concentration of remaining Photo-Acid Generator (PAG) for the active metrology plane.
- No values are available for regions outside the resist, these are shown as solid color.
- Normal ‘latent image before PEB’ metrics are displayed provided the specified measurement height only contains resist, otherwise zeros are returned.
- Exchange graph will result in a profile view following that behaves much like that for ‘image in resist’



X Axis: X Position (nm)

Y Axis: Z Position (nm)

Z Axis: Relative PAC Concentration

Metrology Plane: Y

Metrology Index (nm): 0.0

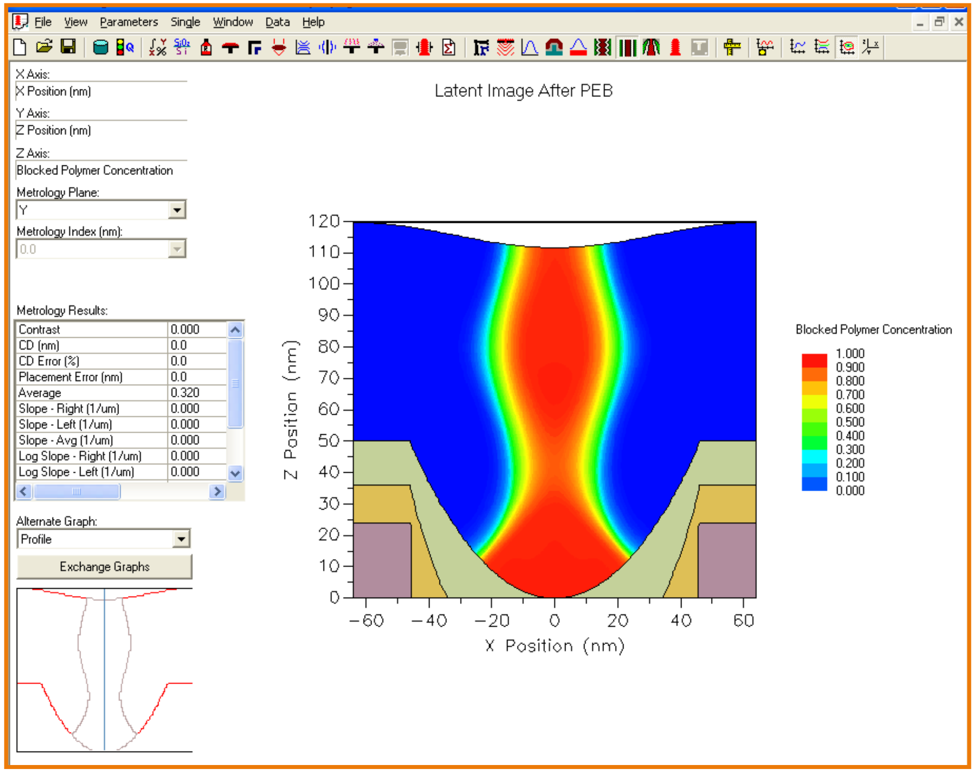
Metrology Results:

Contrast	0.213
CD (nm)	30.6
CD Error (%)	-17.3
Placement Error (nm)	0.0
PAC Average	0.782
Slope - Right (1/um)	7.555
Slope - Left (1/um)	7.555
Slope - Avg (1/um)	7.555
Log Slope - Right (1/um)	-9.137
Log Slope - Left (1/um)	-9.137

Alternate Graph: Profile

‘Latent Image after PEB’ Output – Main View

- The ‘Latent image after PEB’ view shows the relative concentration of blocked sites for the active metrology plane.
- No values are available for regions outside the resist, these are shown as solid color.
- Normal ‘latent image after PEB’ metrics are displayed provided the specified measurement height only contains resist, otherwise zeros are returned.
- Exchange graph will result in a profile view following that behaves much like that for ‘image in resist’



X Axis:
X Position (nm)
Y Axis:
Z Position (nm)
Z Axis:
Blocked Polymer Concentration
Metrology Plane:
Y
Metrology Index (nm):
0.0

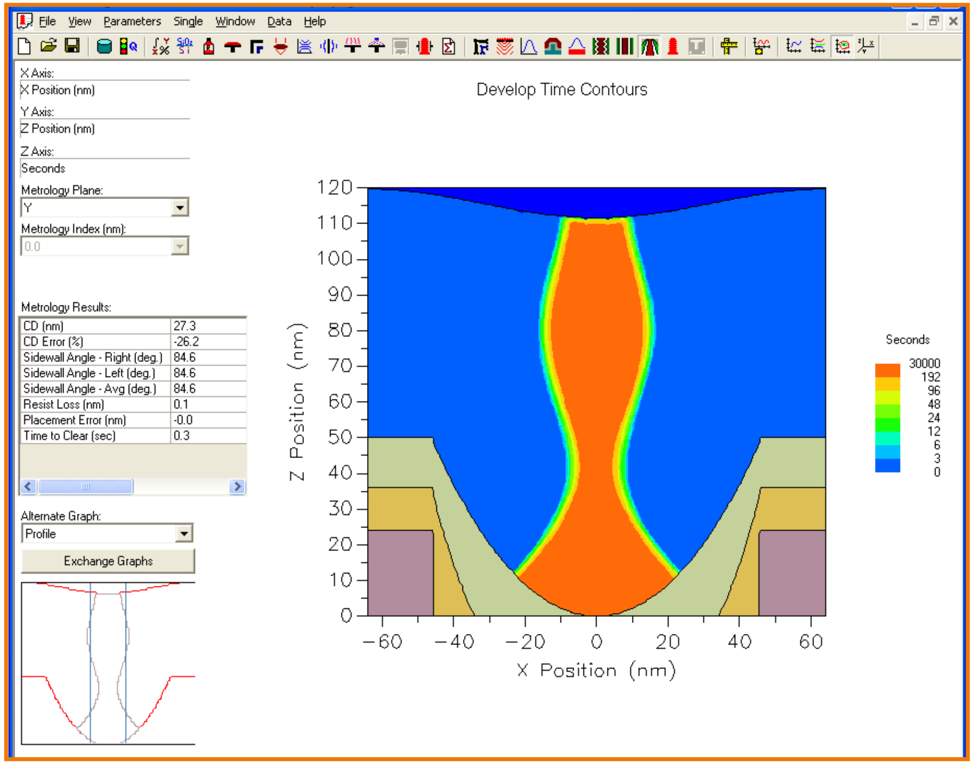
Metrology Results:

Contrast	0.000
CD (nm)	0.0
CD Error (%)	0.0
Placement Error (nm)	0.0
Average	0.320
Slope - Right (1/um)	0.000
Slope - Left (1/um)	0.000
Slope - Avg (1/um)	0.000
Log Slope - Right (1/um)	0.000
Log Slope - Left (1/um)	0.000

Alternate Graph:
Profile

‘Develop Time Contours’ Output – Main View

- The ‘Develop Time Contours’ view shows the evolution of the resist feature during the development process. Each contour represents the feature at a particular development time.
- No values are available for regions outside the resist, these are shown as solid color.
- The metrology results are the same as those reported in the ‘resist profile’ output screen.
- Exchange graph will result in a profile view following that behaves much like that for ‘image in resist’



X Axis: X Position (nm)

Y Axis: Z Position (nm)

Z Axis: Seconds

Metrology Plane: Y

Metrology Index (nm): 0.0

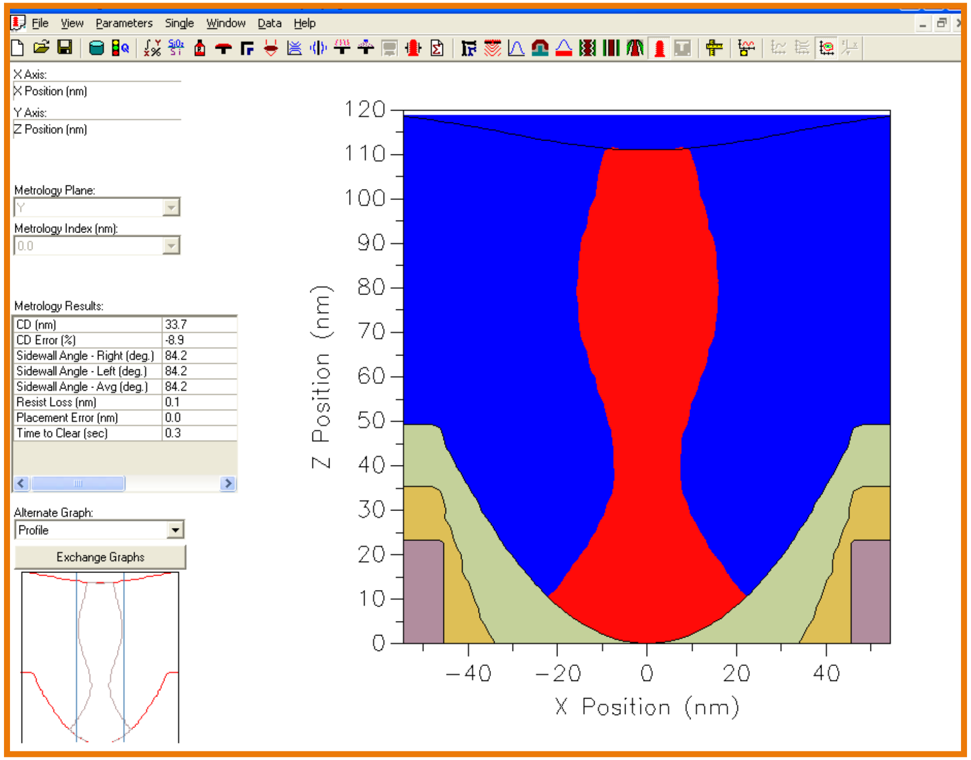
Metrology Results:

CD (nm)	27.3
CD Error (%)	-26.2
Sidewall Angle - Right (deg.)	84.6
Sidewall Angle - Left (deg.)	84.6
Sidewall Angle - Avg (deg.)	84.6
Resist Loss (nm)	0.1
Placement Error (nm)	-0.0
Time to Clear (sec)	0.3

Alternate Graph: Profile

‘Resist Profile’ Output – 2D

- The 2D ‘resist profile’ output screen shows the resist features in the current active metrology plane, Topography coplanar with the resist is also displayed.
- The CD dimensions reported are calculated using the new “collapse resist volume” method detailed on subsequent slides.
- Exchange graph will result in a contour plot outlining the resist feature in grey. The upper and lower bounds of the original resist region are shown in red and blue vertical lines are included to indicate where the CD measurement has been taken.



X Axis:
X Position (nm)

Y Axis:
Z Position (nm)

Metrology Plane: Y

Metrology Index (nm): 0.0

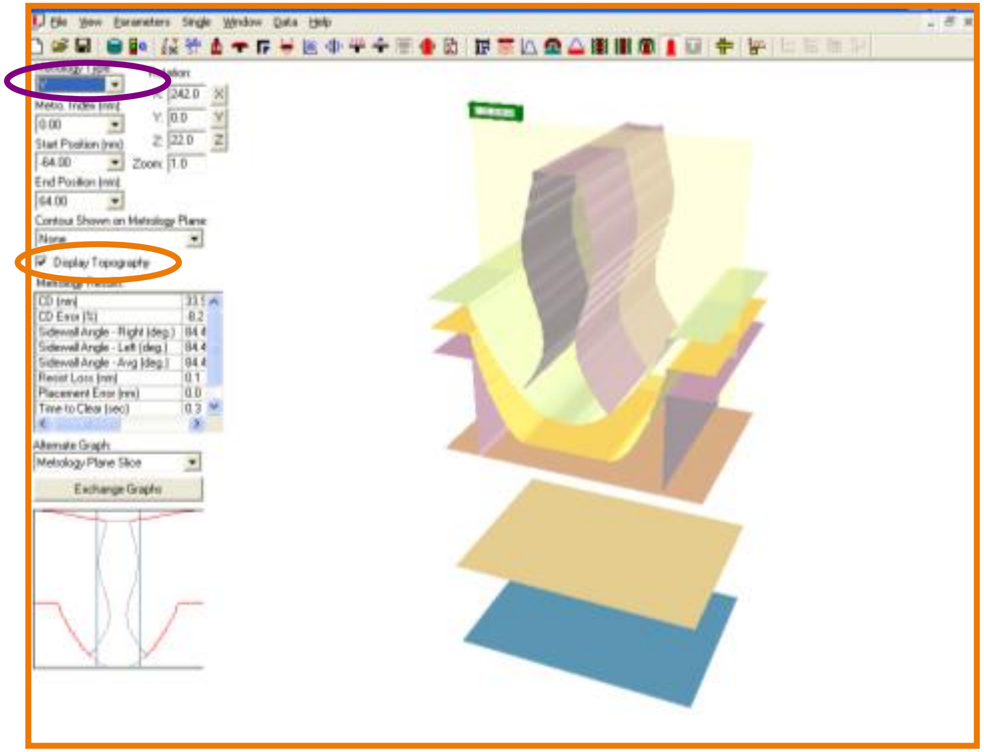
Metrology Results:

CD (nm)	33.7
CD Error (%)	-8.9
Sidewall Angle - Right (deg.)	84.2
Sidewall Angle - Left (deg.)	84.2
Sidewall Angle - Avg (deg.)	84.2
Resist Loss (nm)	0.1
Placement Error (nm)	0.0
Time to Clear (sec)	0.3

Alternate Graph: Profile

‘Resist Profile’ Output – 3D

- The 3D ‘resist profile’ output screen shows the resist features in the sim region and the topography stack.
- Topography stack can be toggled ‘on/off’ using **check box**.
- The CD dimensions reported are calculated using the new “collapse resist volume” for the active metrology plane (transparent plane).
- Select **metrology plane using drop-down list** – including new ‘top-down z’ view – see later slides
- Rotate 3D view using <shift> and mouse
- Exchange graph gives contour plot for the active metrology plane.



Rotation:
X: 242.0
Y: 0.0
Z: 22.0
Zoom: 1.0

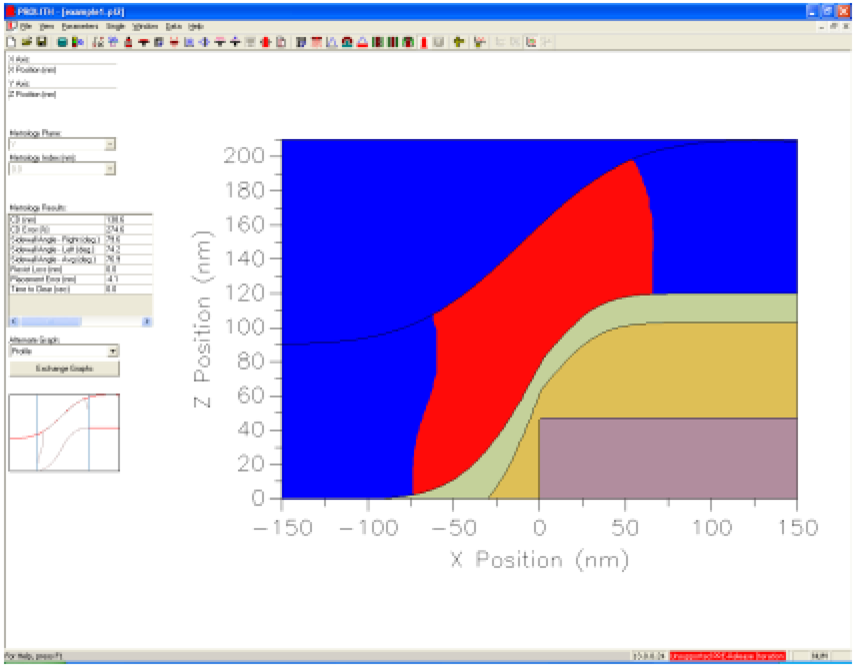
Metro. Index (nm): 0.00
Start Position (nm): -64.00
End Position (nm): 64.00
Contour Shown on Metrology Plane: None
☑ Display Topography

CD (nm)	33.
CD Error (%)	-8.2
Sidewall Angle - Right (deg.)	84.
Sidewall Angle - Left (deg.)	84.4
Sidewall Angle - Avg (deg.)	84.4
Resist Loss (nm)	0.1
Placement Error (nm)	0.0
Time to Clear (sec)	0.3

Alternate Graph: Metrology Plane Slice

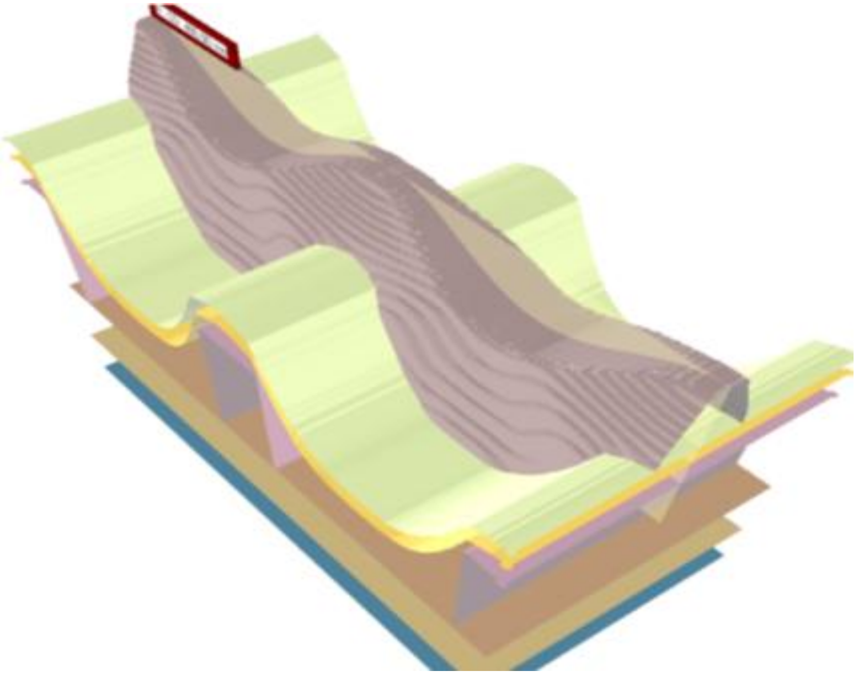
Metrology Issues: The Problem - Case 1

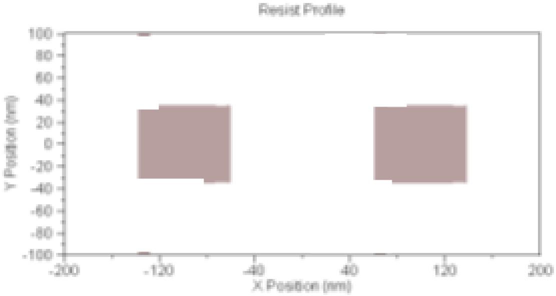
- How do we measure CD when the feature straddles topography?
- Really want to mimic top-down CD SEM behavior.
- Traditional PROLITH metrology would return the width of the resist volume at a particular z height. Obviously, this would not be the desired output in this case.



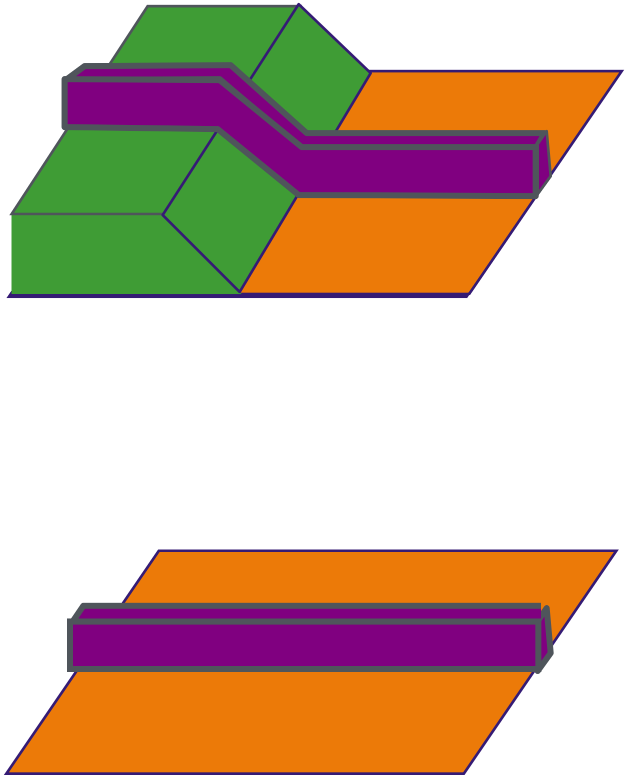
Metrology Issues: The Problem – Case 2

- How do we extract the contour of a line crossing topography?
- Again, we really want to mimic top-down CD SEM behavior.
- Extracting a z contour at a fixed height doesn't reveal a continuous line.





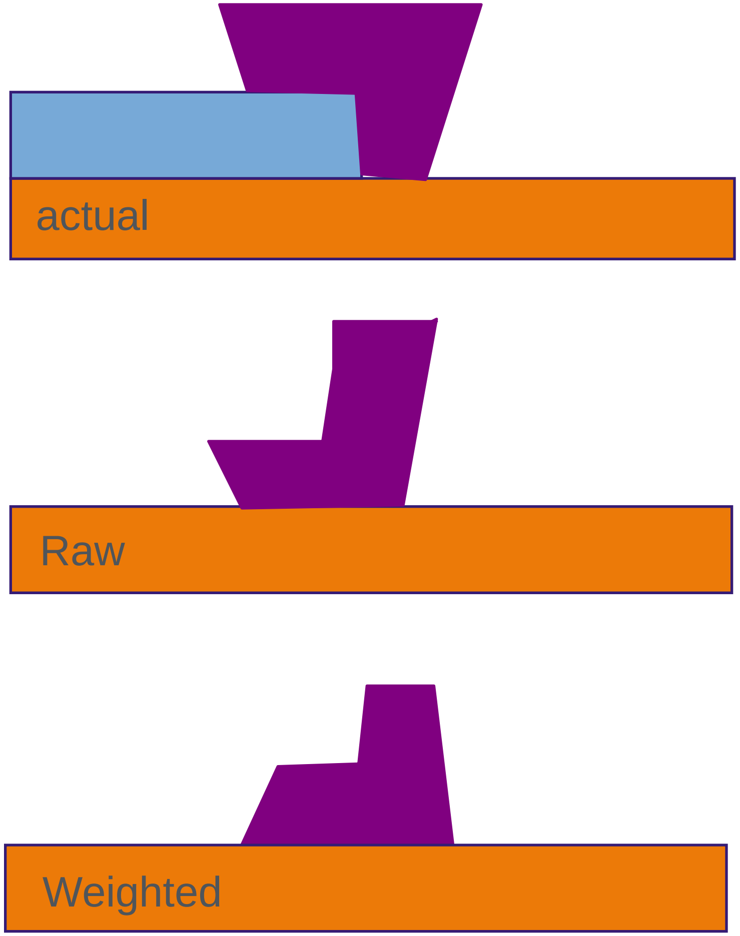
The PROLITH X3 Solution: Collapsed Resist Volume



- Issue: How to define a z-plane. Constant height value could not extract this line.
- Solution: Use weighted profile. Drop all “weight” of resist to flat plane then use %age height or constant height from that plane.
- When wafer topography is active, X and Y plane metrology performed upon the collapsed volume. Additionally, a “top down z-plane’ is available which shows z-contours on the collapsed volume

Raw versus Weighted Profiles

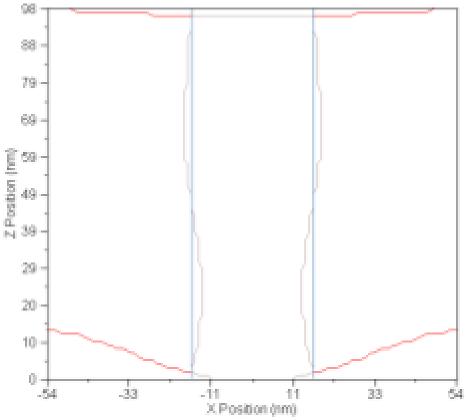
- As with previous PROLITH versions the collapsed volume can be used for raw or weighted measurements.
- In the ‘***raw method’*** the profile is collapsed to the substrate with it’s basic profile shape remaining in tact, i.e. a re-entrant profile will remain a re-entrant profile.
- In the ‘***weighted method***’ all of the mass of resist over a given point is dropped to the collapsed plane. Thus a re-entrant profile will become prograde. This more mimics the behavior of a top-down CD SEM.

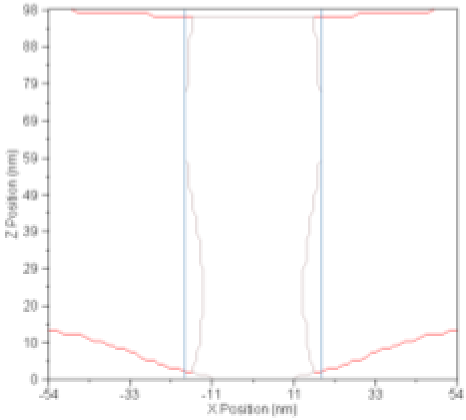


Using the Collapsed Volume

- When wafer topography is active, its recommended that
  - Only an ***‘Absolute Measurement Height’*** is employed.
  - The Measurement Height should be kept to less that half the nominal resist thickness, ideally 0 – 25%.
- Choosing the raw collapsed volume and a measurement height of 0 nm measures the CD between the points where the resist contacts the material beneath it
- Choosing a weighted collapsed volume and a measurement height of 0 nm measures the CD at the widest point of the feature.

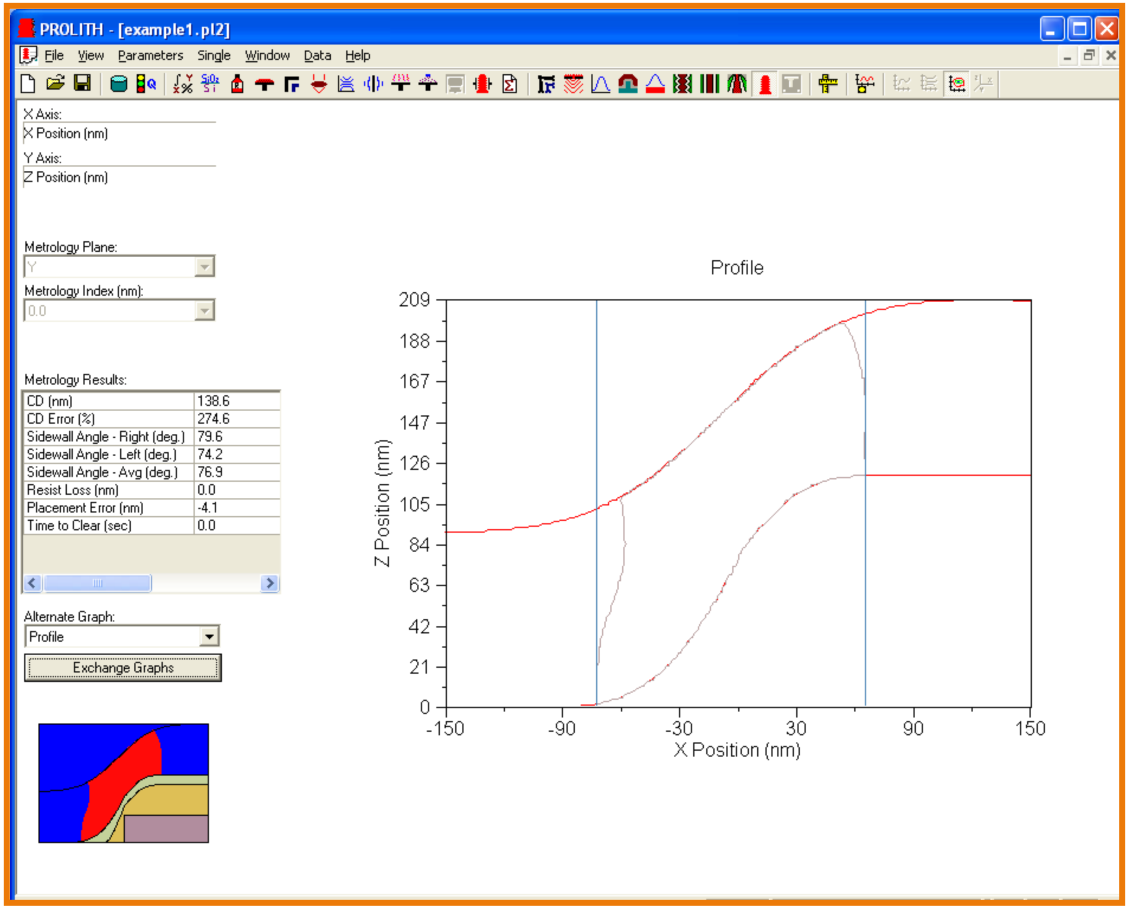
Raw Collapsed Volume
0 nm Height





Weighted Collapsed Volume
0 nm Height

Collapsed Volume: Case 1



X Axis: X Position (nm)

Y Axis: Z Position (nm)

Metrology Plane: Y

Metrology Index (nm): 0.0

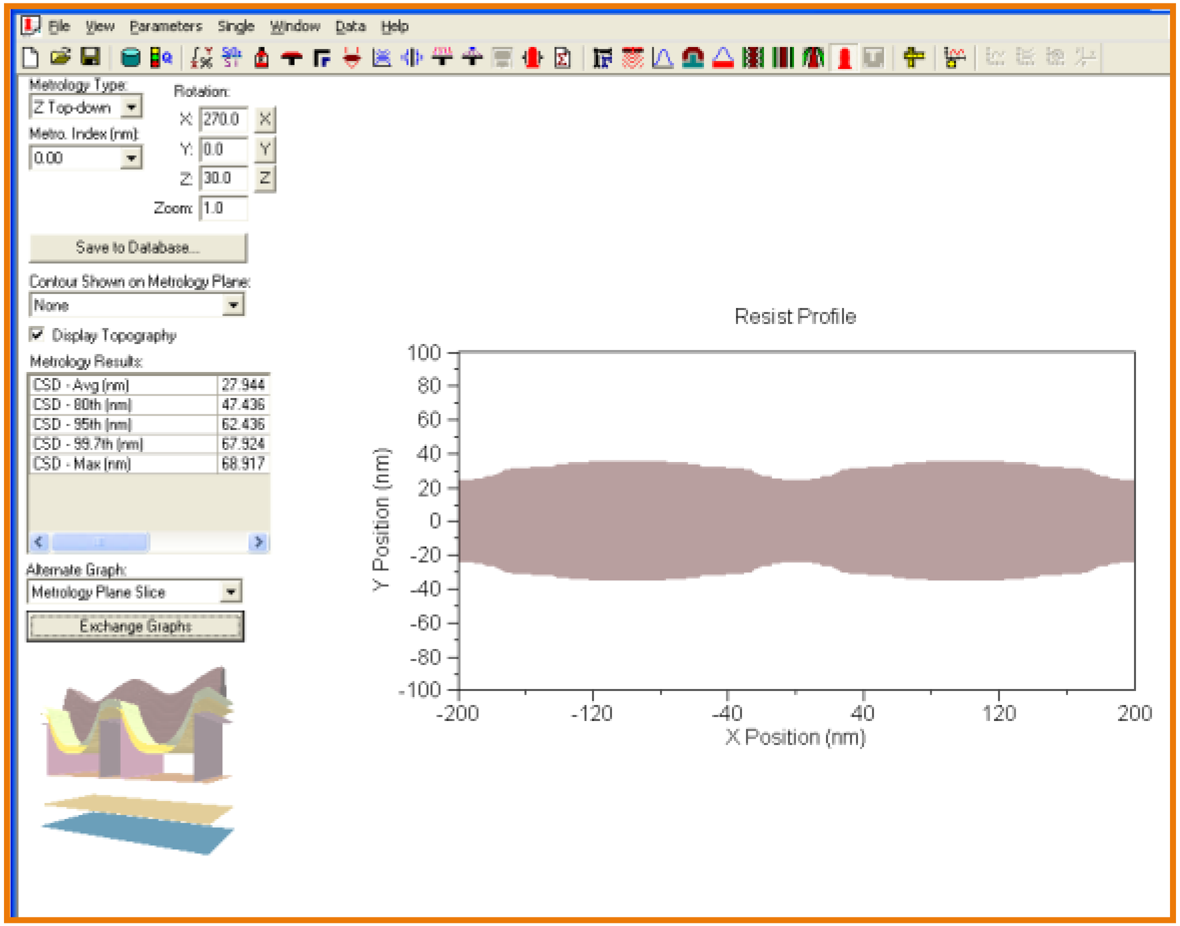
Metrology Results:

CD (nm)	138.6
CD Error (%)	274.6
Sidewall Angle - Right (deg.)	79.6
Sidewall Angle - Left (deg.)	74.2
Sidewall Angle - Avg (deg.)	76.9
Resist Loss (nm)	0.0
Placement Error (nm)	-4.1
Time to Clear (sec)	0.0

Alternate Graph: Profile

Using the Weighted Collapsed Volume
allows a good approximation of real feature width to be obtained

Collapsed Volume: Case 2



Metrology Type: Z Top-down

Metro. Index (nm): 0.00

Rotation:
X: 270.0
Y: 0.0
Z: 30.0
Zoom: 1.0

Contour Shown on Metrology Plane: None

☑ Display Topography

Metrology Results:

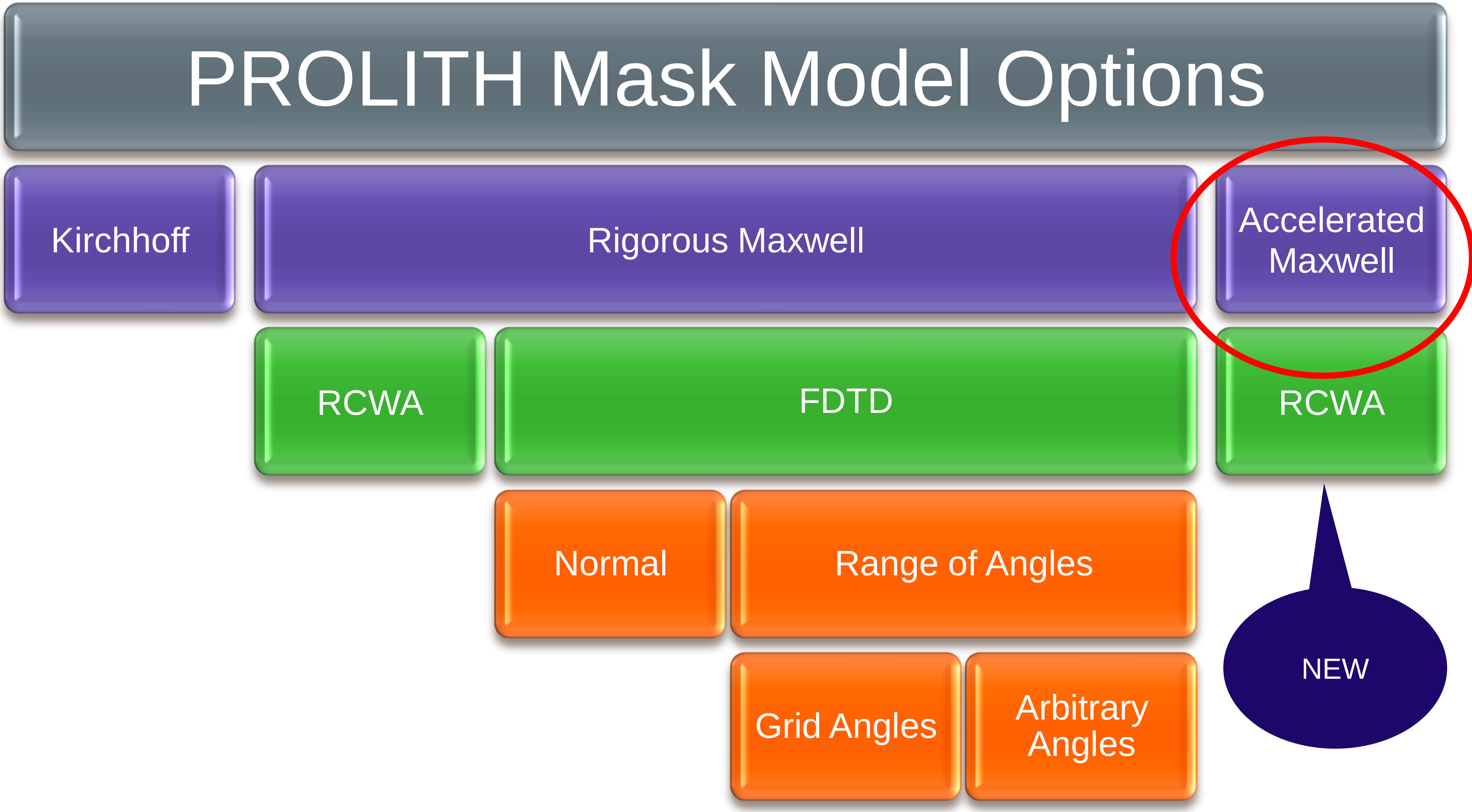
CSD - Avg (nm)	27.944
CSD - 80th (nm)	47.436
CSD - 95th (nm)	62.436
CSD - 99.7th (nm)	67.924
CSD - Max (nm)	68.917

Alternate Graph: Metrology Plane Slice

Using the Collapsed Volume and the z top-down plane allows a good approximation of an SEM contour to be obtained

Mask Model Updates

PROLITH Mask Model Options



PROLITH Mask Model Options

Kirchhoff

Rigorous Maxwell

Accelerated Maxwell

RCWA

FDTD

RCWA

Normal

Range of Angles

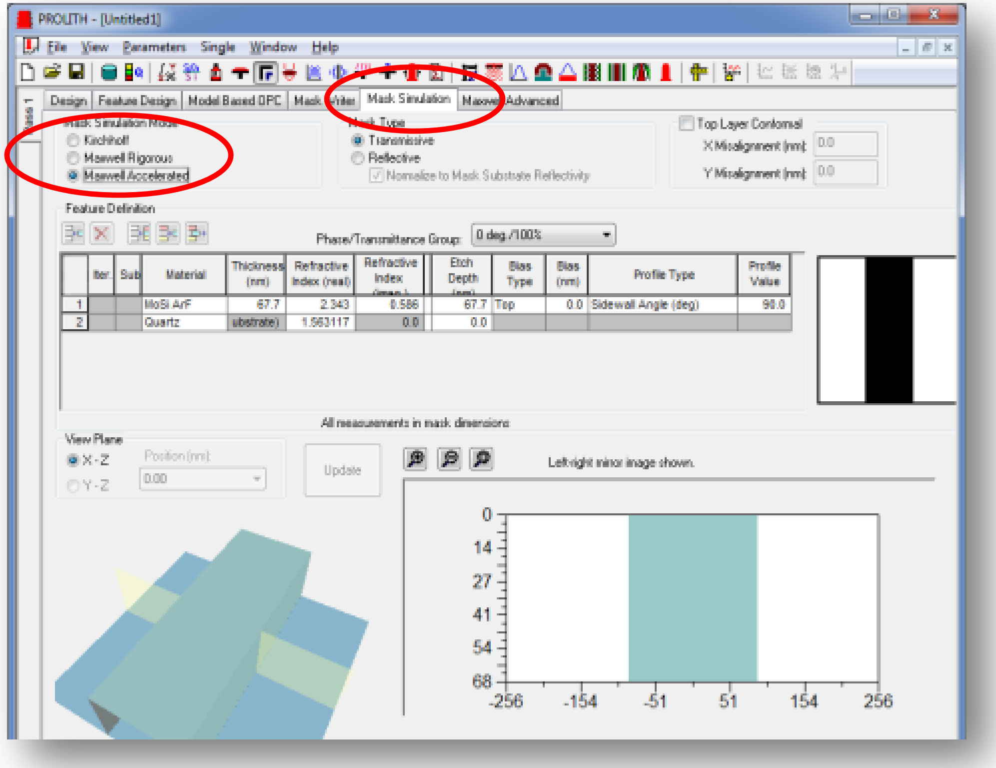
Grid Angles

Arbitrary Angles

NEW

New Mask Simulation mode – Maxwell Accelerated

- New mask simulation mode ‘Maxwell Accelerated’ in addition to ‘Kirchhoff’ and ‘Maxwell Rigorous’
- This option is only applicable for ‘Manhattan’ masks (e.g. features running horizontal and vertical – 90 degrees)
- Available for all monochromatic technologies
- Uses domain decomposition approach
- RCWA algorithms used (FDTD not available with this approach)



Mask Simulation Mode
○ Kirchhoff
○ Maxwell Rigorous
● Maxwell Accelerated

Mask Type
● Transmissive
○ Reflective
☑ Normalize to Mask Substrate Reflectivity

☐ Top Layer Conformal
X Misalignment (nm): 0.0
Y Misalignment (nm): 0.0

Phase/Transmittance Group: 0 deg./100%

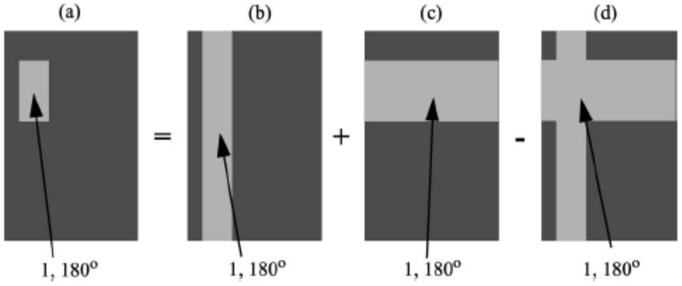
	Iter.	Sub	Material	Thickness (nm)	Refractive Index (real)	Refractive Index (imag.)	Etch Depth (nm)	Bias Type	Bias (nm)	Profile Type	Profile Value
1			MoSi ArF	67.7	2.343	0.586	67.7	Top	0.0	Sidewall Angle (deg)	90.0
2			Quartz	(substrate)	1.563117	0.0	0.0				

All measurements in mask dimensions

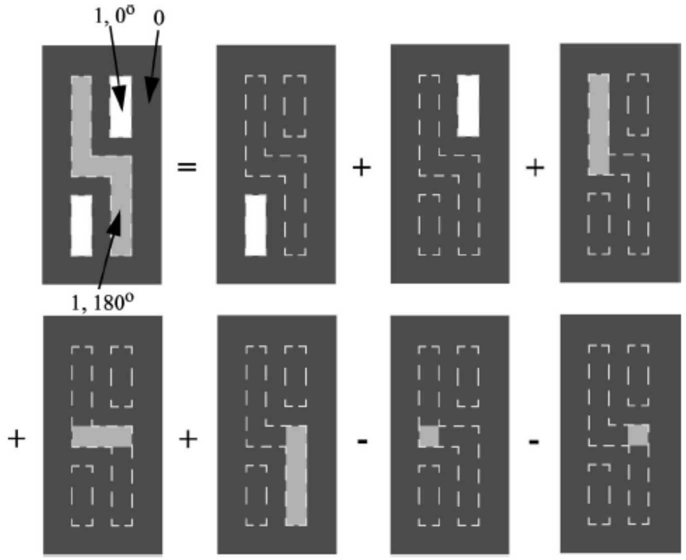
View Plane
● X-Z
○ Y-Z
Position (nm): 0.00

Left-right mirror image shown.

Accelerated Mask EMF Formulation



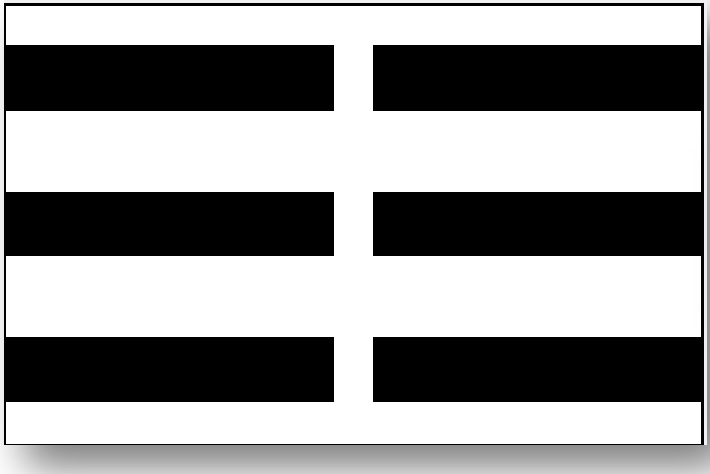
Step 1: Construction of 2D Rectangles from 1D simulations

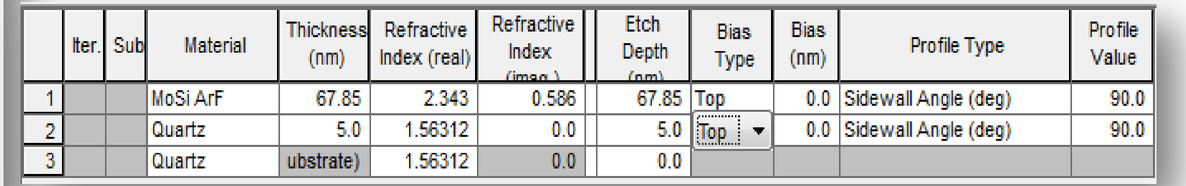


Step 2: Stitching Rectangles into 2D Manhattan Polygons

- Based on the idea by Kostas Adam (from Andy Neureuther group).
- Same ideas investigated by Andreas Erdmann for both ArF and EUV.

Accelerated EMF – Example 1





	Iter.	Sub	Material	Thickness (nm)	Refractive Index (real)	Refractive Index (imag.)	Etch Depth (nm)	Bias Type	Bias (nm)	Profile Type	Profile Value
1			MoSi ArF	67.85	2.343	0.586	67.85	Top	0.0	Sidewall Angle (deg)	90.0
2			Quartz	5.0	1.56312	0.0	5.0	Top	0.0	Sidewall Angle (deg)	90.0
3			Quartz	ubstrate)	1.56312	0.0	0.0				

* Simulation run on 8 Core PC

	Aerial Image CD			Execution Time*		
Set-up	Kirchhoff - nm	Rigorous (FDTD) -nm	Accelerated EMF - nm	Rigorous (FDTD) - Seconds	Accelerated EMF - Seconds	Speed-up
1 Angle	76.6	59.2	61.6	1315	26	51
5 Angles (Grid)	76.6	58.3	60.1	30156	129	234
9 Angles (Grid)	76.6	57.7	60.1	63920	233	274

Rigorous and Accelerated provides similar results

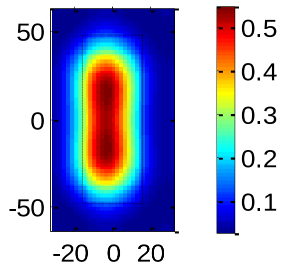
Up to 250x Faster

Benefit of Accelerated EMF Option – Example 2

Rigorous

~70 minutes

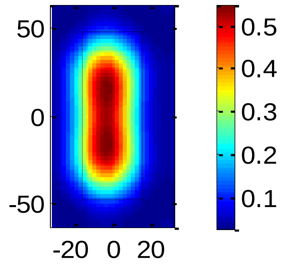
Rigorous



ast EMF, Mean error = -0.40%, RMS error = 0.93%

Accelerated

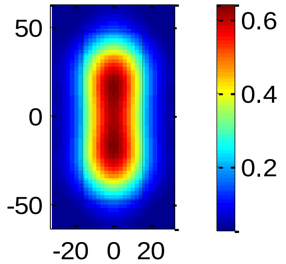
~30 seconds



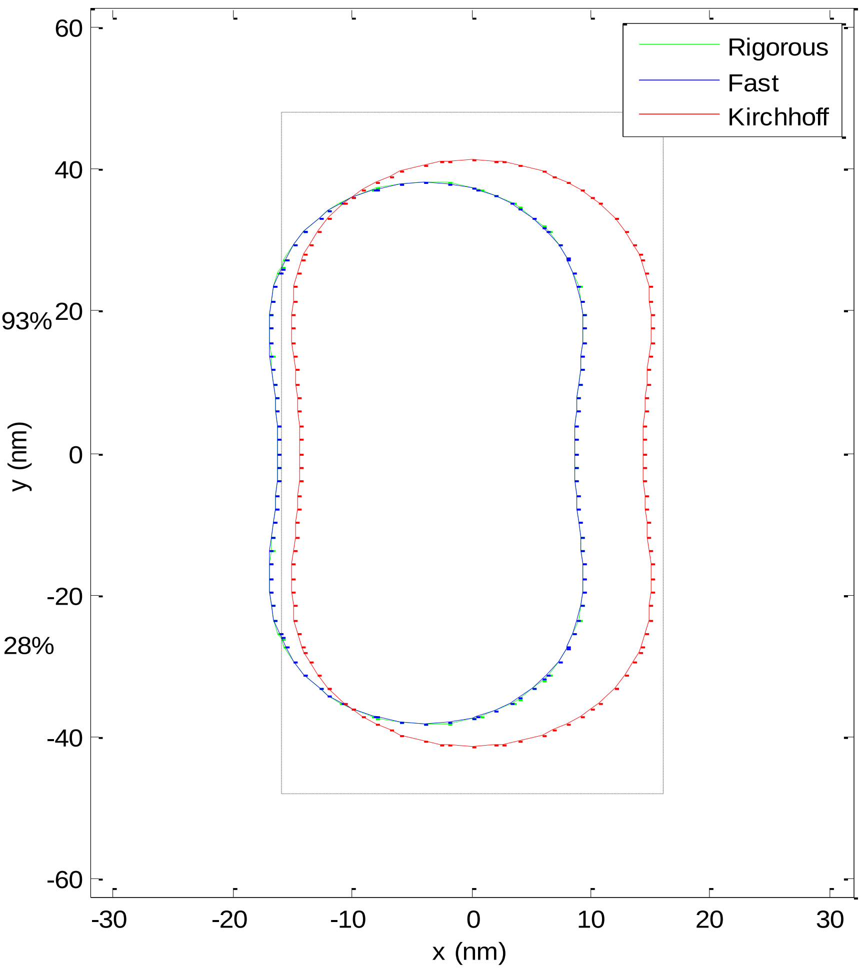
irchhoff, Mean error = 26.64%, RMS error = 47.28%

Kirchhoff

~1 second



Contour Comparison



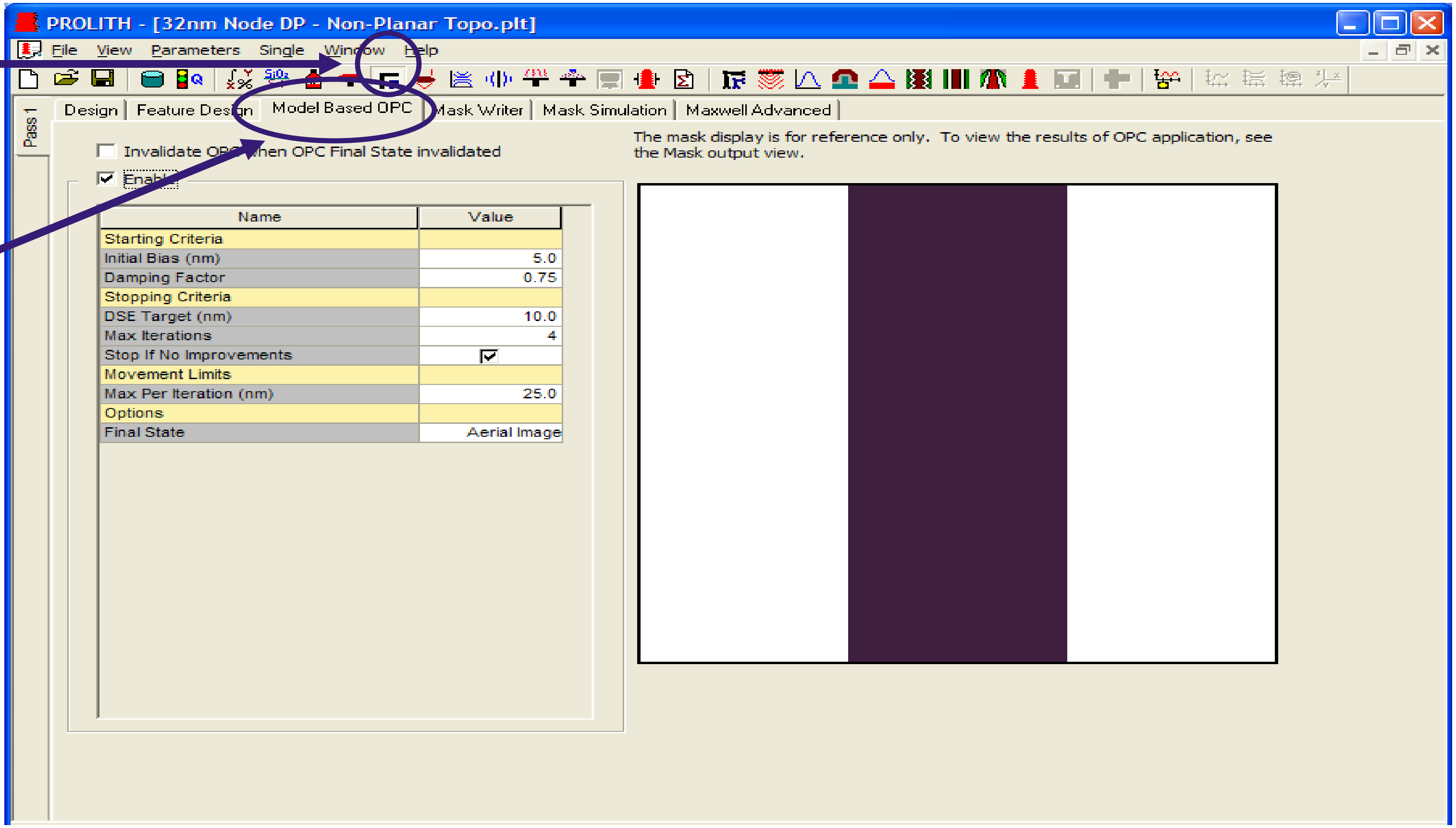
Rigorous and Accelerated contours are exactly on top of each other

1D OPC - Feature detail

- PROLITH 10.2 and higher allows users to apply model based OPC to 2D mask patterns.
- With PROLITH X3, model based OPC can also be applied to 1D mask patterns

Mask Window

Model Based OPC tab



☐ Invalidate OPC when OPC Final State invalidated

☑ Enable

Name	Value
Starting Criteria	
Initial Bias (nm)	5.0
Damping Factor	0.75
Stopping Criteria	
DSE Target (nm)	10.0
Max Iterations	4
Stop If No Improvements	☑
Movement Limits	
Max Per Iteration (nm)	25.0
Options	
Final State	Aerial Image

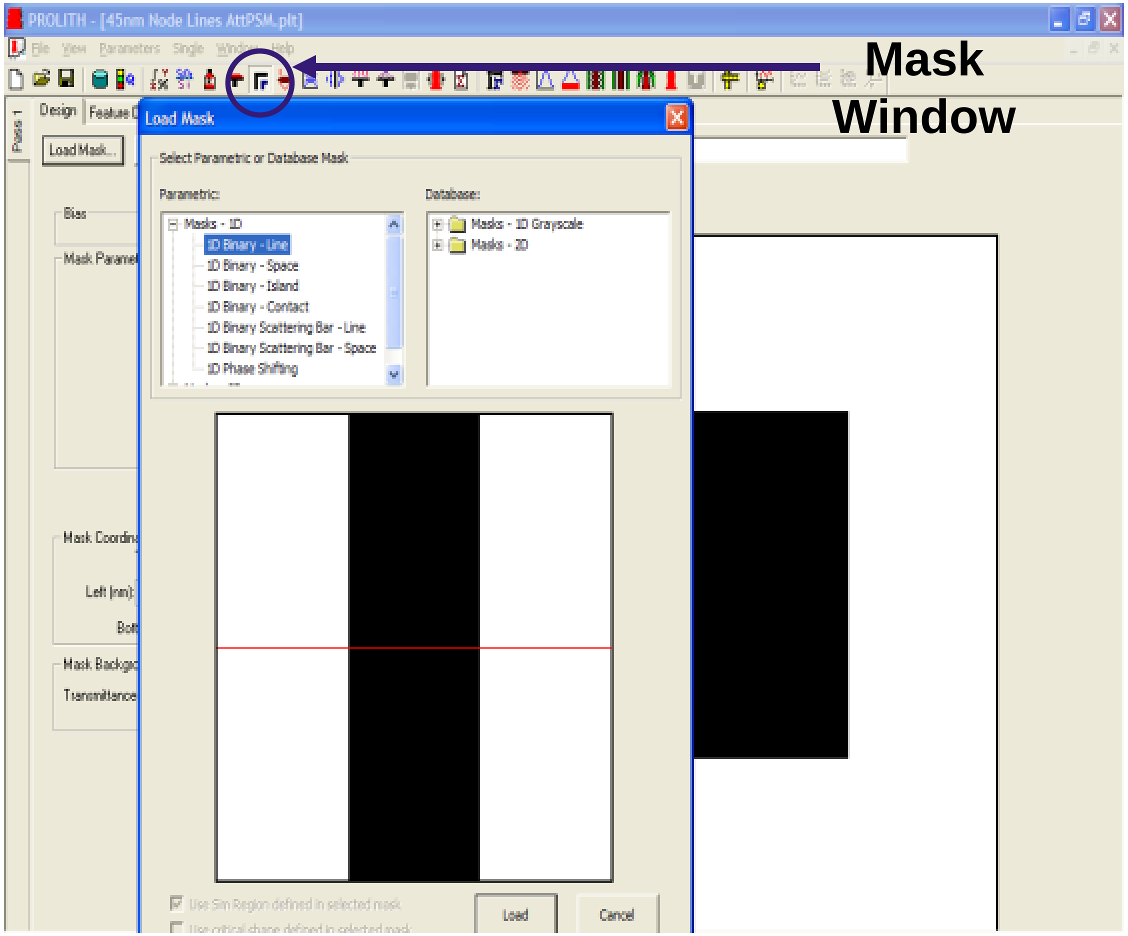
The mask display is for reference only. To view the results of OPC application, see the Mask output view.

1D OPC Set-up

- Step 1: Load Parametric Mask
- Step 2: Set anchor feature target and calculate anchor dose
- Step 3: Set feature sizes and pitch to OPC
- Step 4: Set OPC Parameters
- Step 5: Run OPC and View Results

Step 1 – Load parametric mask

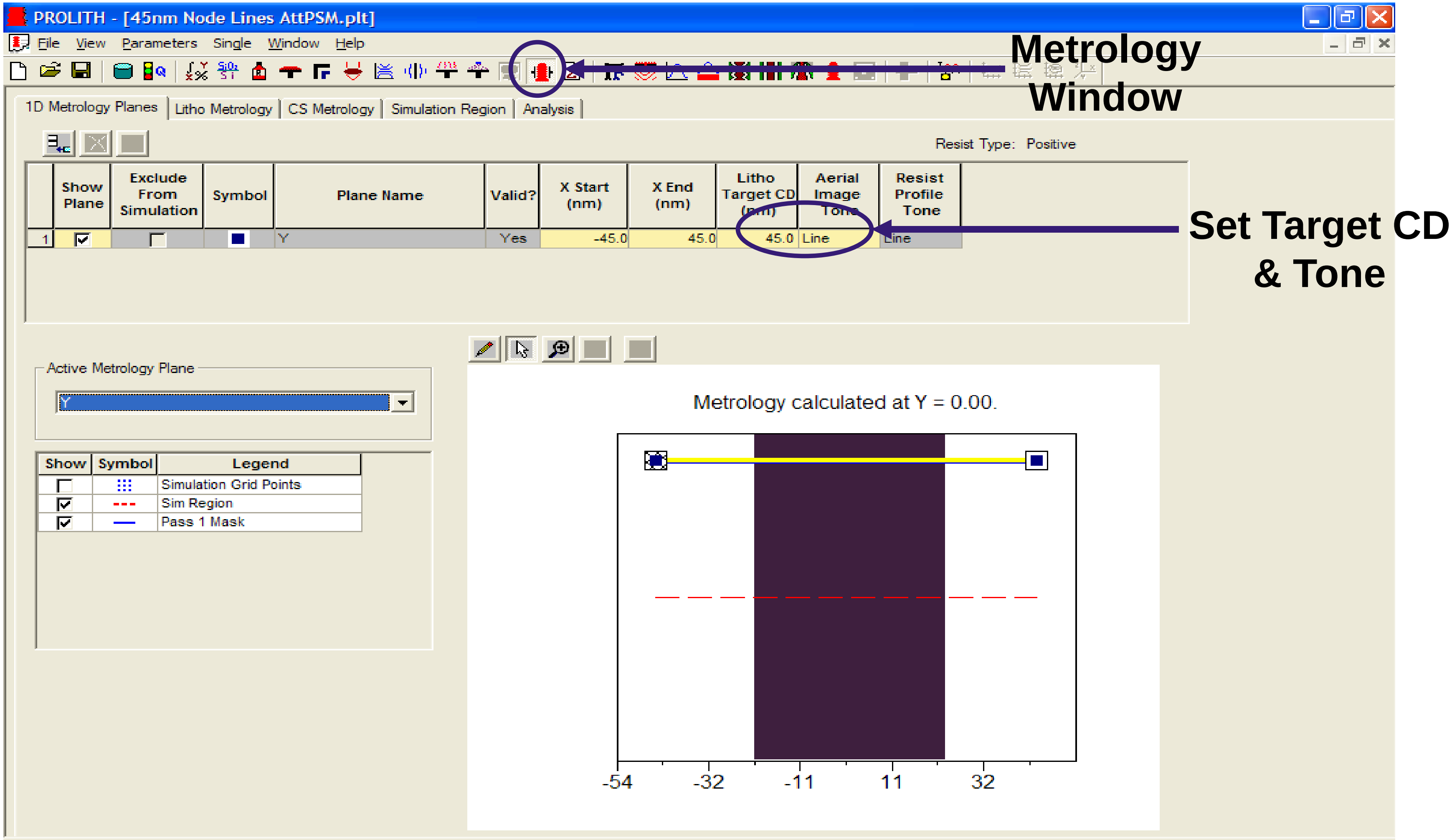
- On Mask window, load any of the following parametric masks
    - 1D Line
    - 1D Space
    - 1D Line with Assist Features
    - 1D Space with Assist Features
    - 1D Island
    - 1D Contact
- Set feature size and pitch of anchor feature.



☑ Use Sim Region defined in selected mask

☐ Use critical shape defined in selected mask

Step 2 – Set anchor feature target and calculate anchor dose



Metrology Window

Set Target CD & Tone

Resist Type: Positive

	Show Plane	Exclude From Simulation	Symbol	Plane Name	Valid?	X Start (nm)	X End (nm)	Litho Target CD (nm)	Aerial Image Tone	Resist Profile Tone
1	☑	☐	■	Y	Yes	-45.0	45.0	45.0	Line	Line

Active Metrology Plane: Y

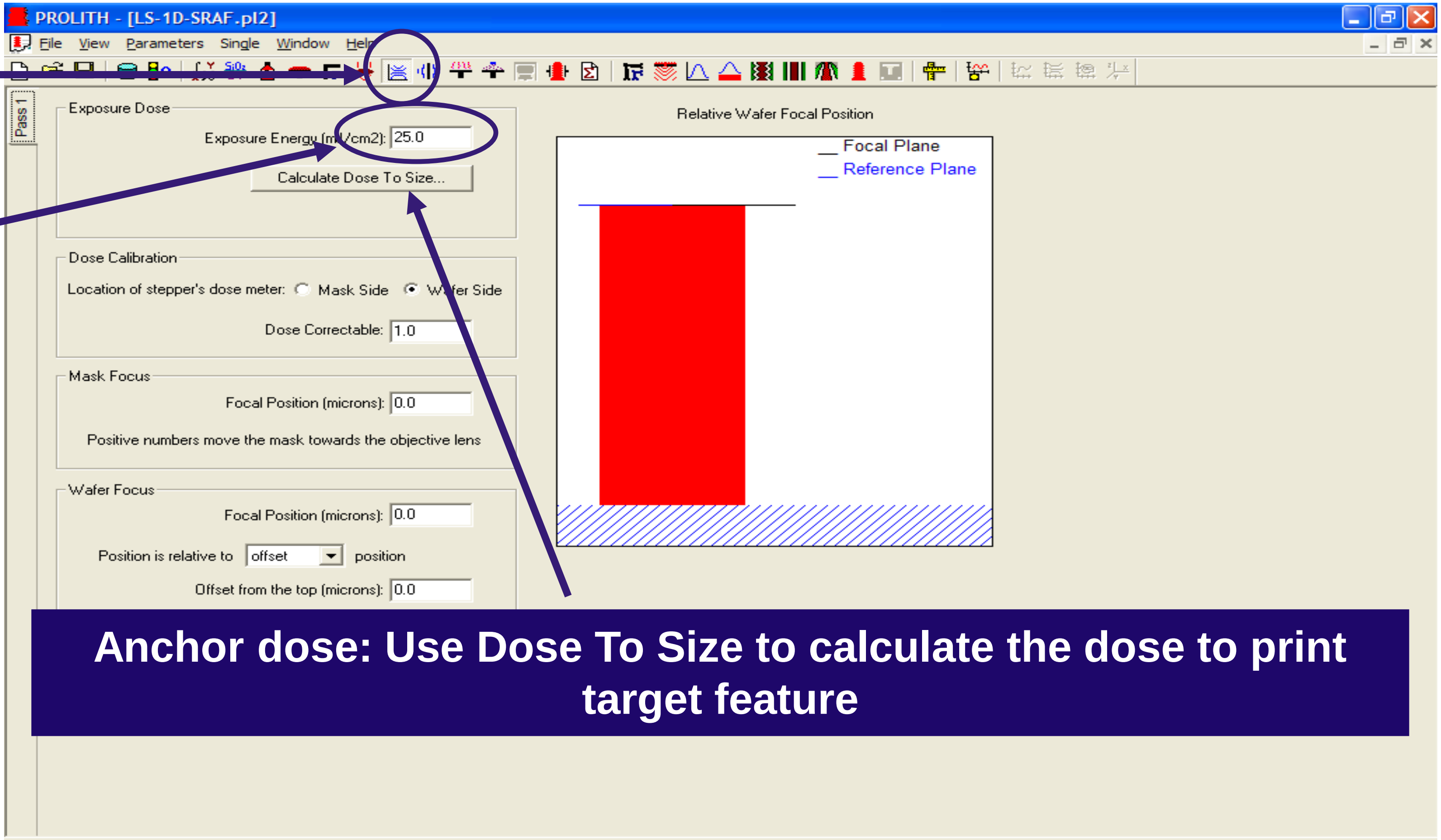
Show	Symbol	Legend
☐	⁞⁞⁞	Simulation Grid Points
☑	---	Sim Region
☑	—	Pass 1 Mask

Metrology calculated at Y = 0.00.

Step 2 – Set anchor feature target and calculate anchor dose

Focus Exposure Window

Dose



Exposure Dose

Exposure Energy (mJ/cm2): 25.0

Dose Calibration

Location of stepper's dose meter: ○ Mask Side ● Wafer Side

Dose Correctable: 1.0

Mask Focus

Focal Position (microns): 0.0

Positive numbers move the mask towards the objective lens

Wafer Focus

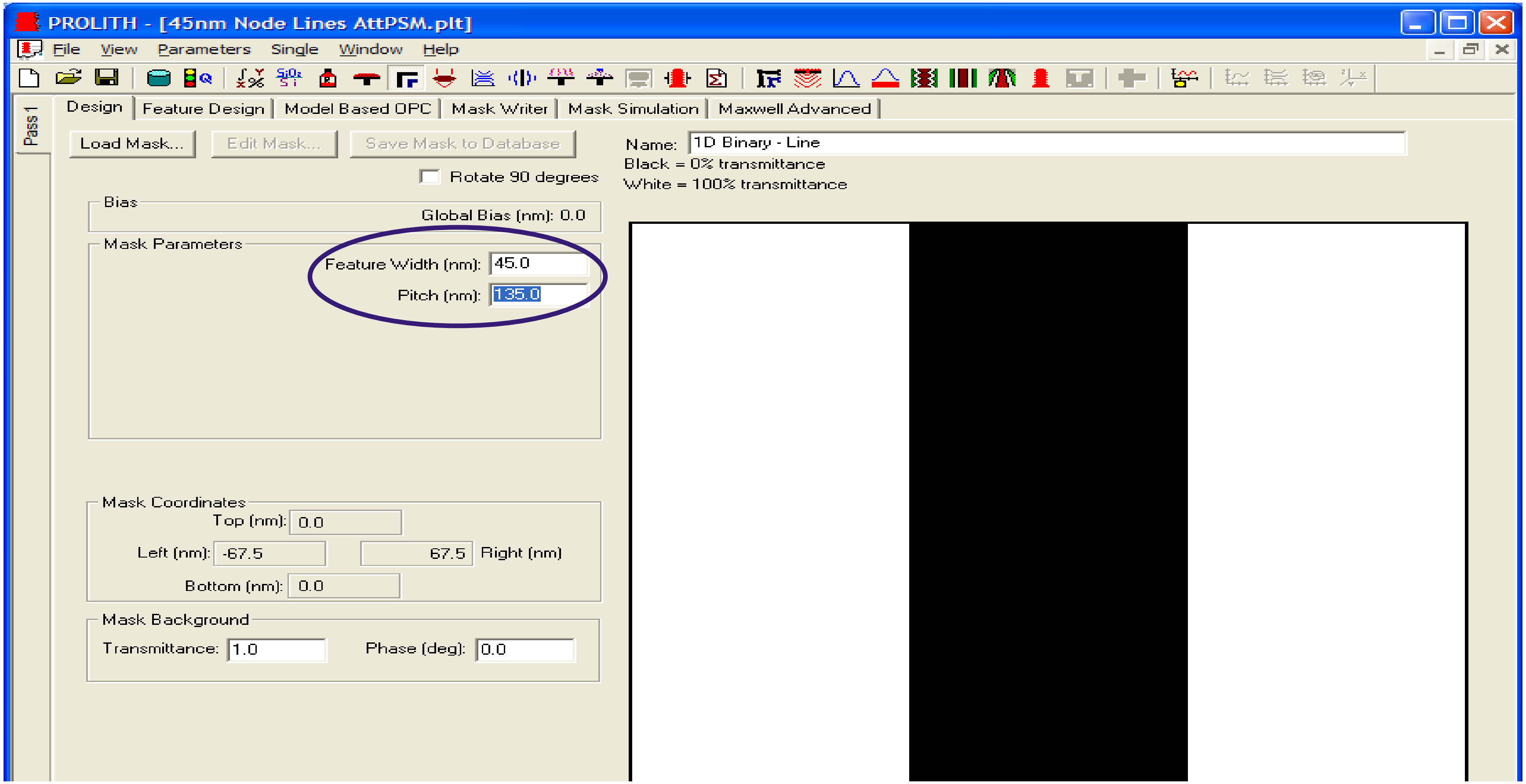
Focal Position (microns): 0.0

Position is relative to offset position

Offset from the top (microns): 0.0

Anchor dose: Use Dose To Size to calculate the dose to print target feature

Step 3 - Set feature sizes and pitch to OPC



Name: 1D Binary - Line

Black = 0% transmittance

White = 100% transmittance

☐ Rotate 90 degrees

Bias

Global Bias (nm): 0.0

Mask Parameters

Feature Width (nm): 45.0

Pitch (nm): 135.0

Mask Coordinates

Top (nm): 0.0

Left (nm): -67.5

Right (nm): 67.5

Bottom (nm): 0.0

Mask Background

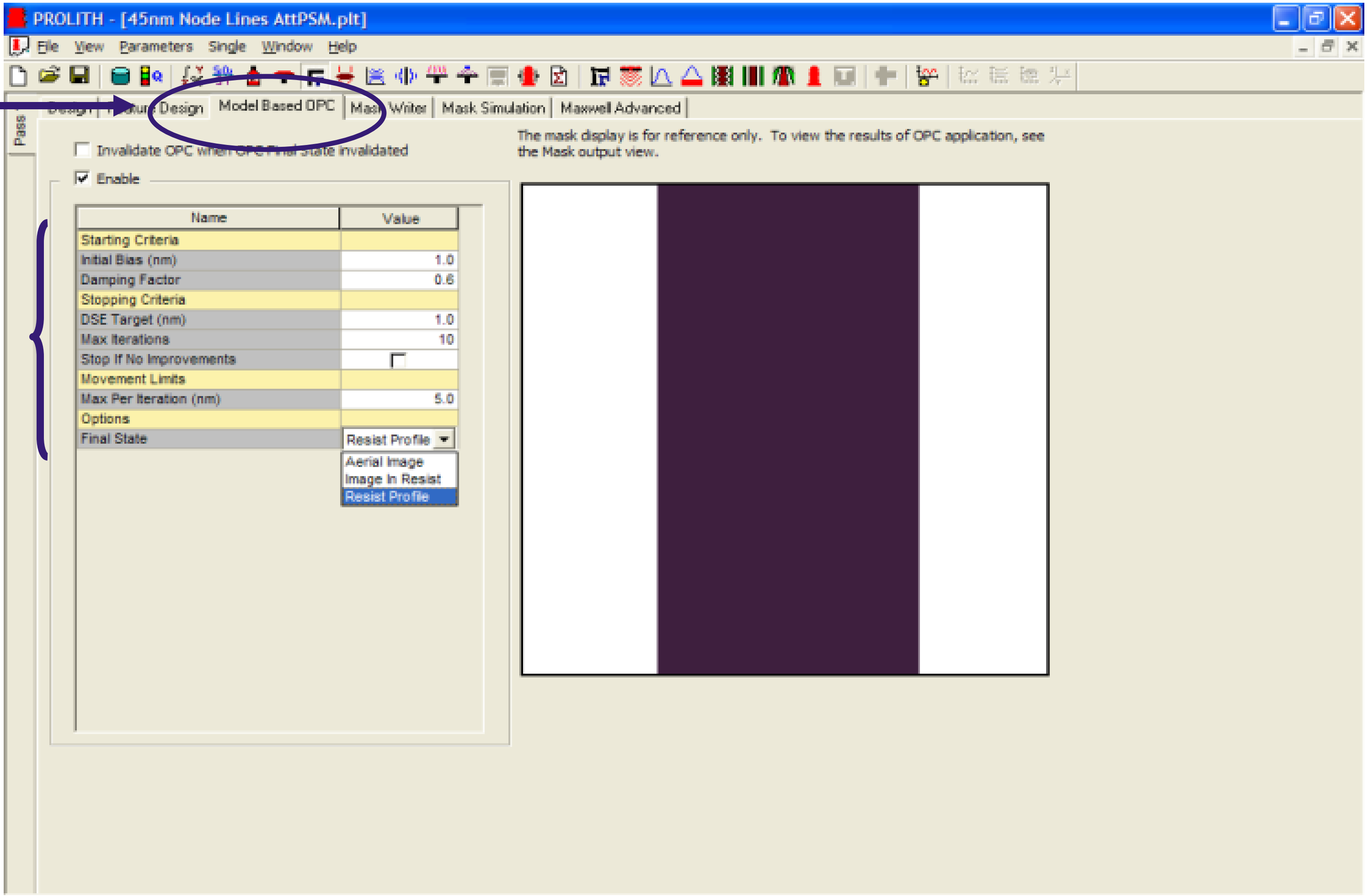
Transmittance: 1.0

Phase (deg): 0.0

Step 4 - Set OPC Parameters

OPC Tab

OPC Parameters



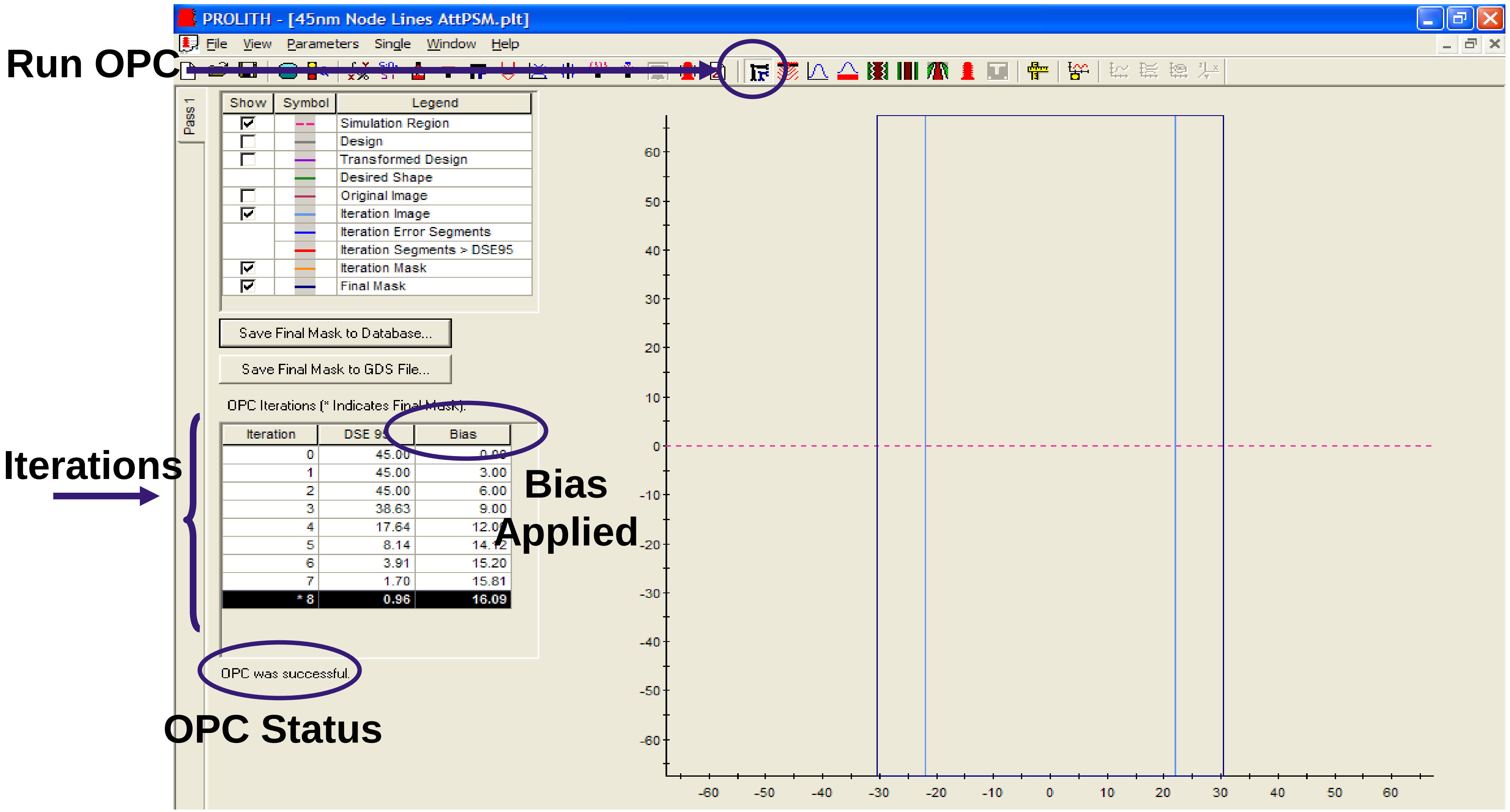
☐ Invalidate OPC when OPC Final State invalidated

☑ Enable

Name	Value
Starting Criteria	
Initial Bias (nm)	1.0
Damping Factor	0.6
Stopping Criteria	
DSE Target (nm)	1.0
Max Iterations	10
Stop If No Improvements	☐
Movement Limits	
Max Per Iteration (nm)	5.0
Options	
Final State	Resist Profile

The mask display is for reference only. To view the results of OPC application, see the Mask output view.

Step 5 – Run OPC and View Results



Run OPC

Show	Symbol	Legend
☑	- -	Simulation Region
☐	—	Design
☐	—	Transformed Design
	—	Desired Shape
☐	—	Original Image
☑	—	Iteration Image
	—	Iteration Error Segments
	—	Iteration Segments > DSE95
☑	—	Iteration Mask
☑	—	Final Mask

OPC Iterations (* Indicates Final Mask).

Iteration	DSE 95	Bias
0	45.00	0.00
1	45.00	3.00
2	45.00	6.00
3	38.63	9.00
4	17.64	12.00
5	8.14	14.12
6	3.91	15.20
7	1.70	15.81
* 8	0.96	16.09

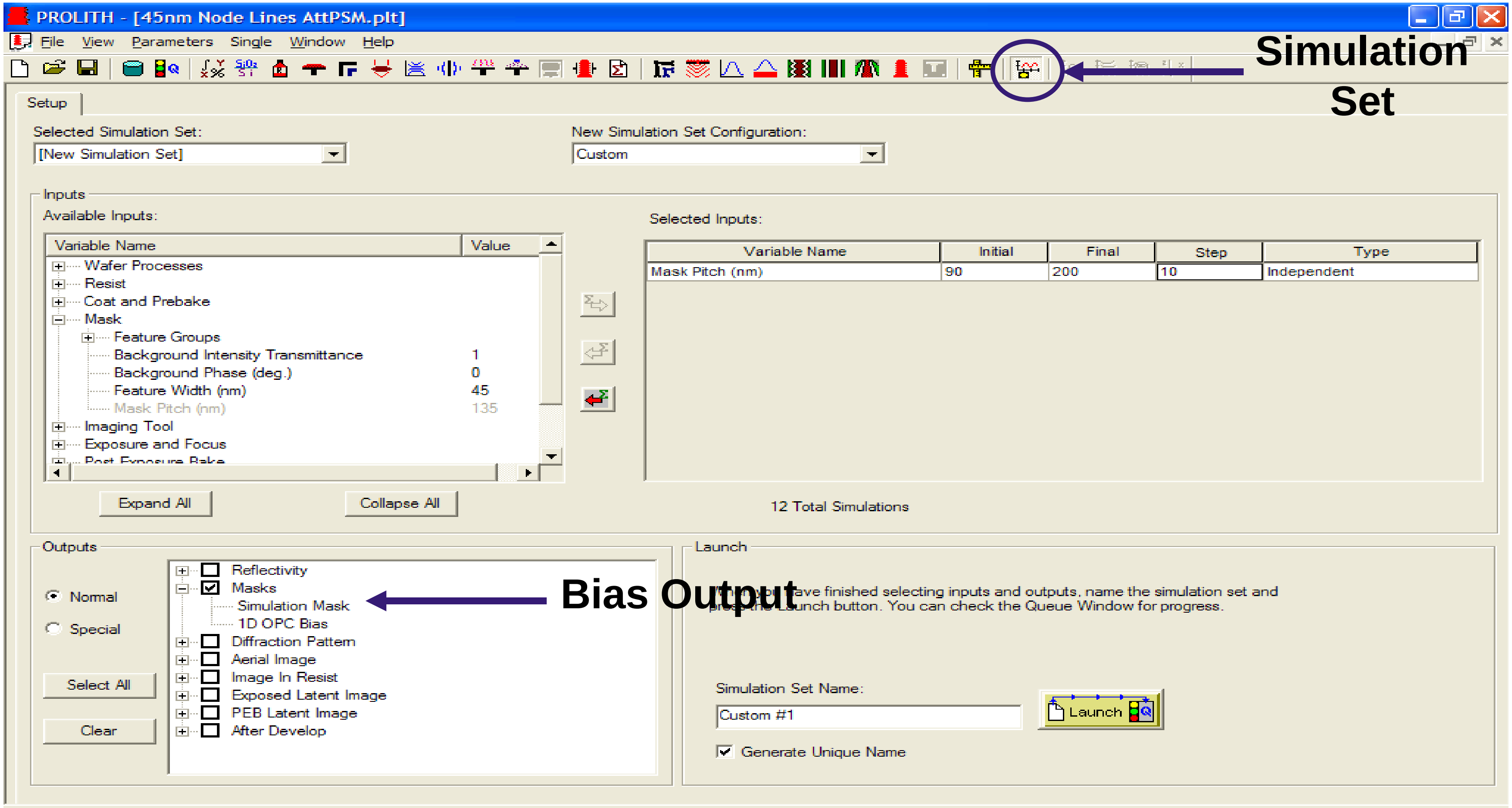
OPC was successful.

Iterations

Bias Applied

OPC Status

Simulation Set – Set-up



Selected Simulation Set: [New Simulation Set]

New Simulation Set Configuration: Custom

Variable Name	Value
Background Intensity Transmittance	1
Background Phase (deg.)	0
Feature Width (nm)	45
Mask Pitch (nm)	135

Selected Inputs:

Variable Name	Initial	Final	Step	Type
Mask Pitch (nm)	90	200	10	Independent

12 Total Simulations

● Normal
○ Special

- ☐ Reflectivity
- ☑ Masks
  - Simulation Mask
  - 1D OPC Bias
- ☐ Diffraction Pattern
- ☐ Aerial Image
- ☐ Image In Resist
- ☐ Exposed Latent Image
- ☐ PEB Latent Image
- ☐ After Develop

ave finished selecting inputs and outputs, name the simulation set and press the Launch button. You can check the Queue Window for progress.

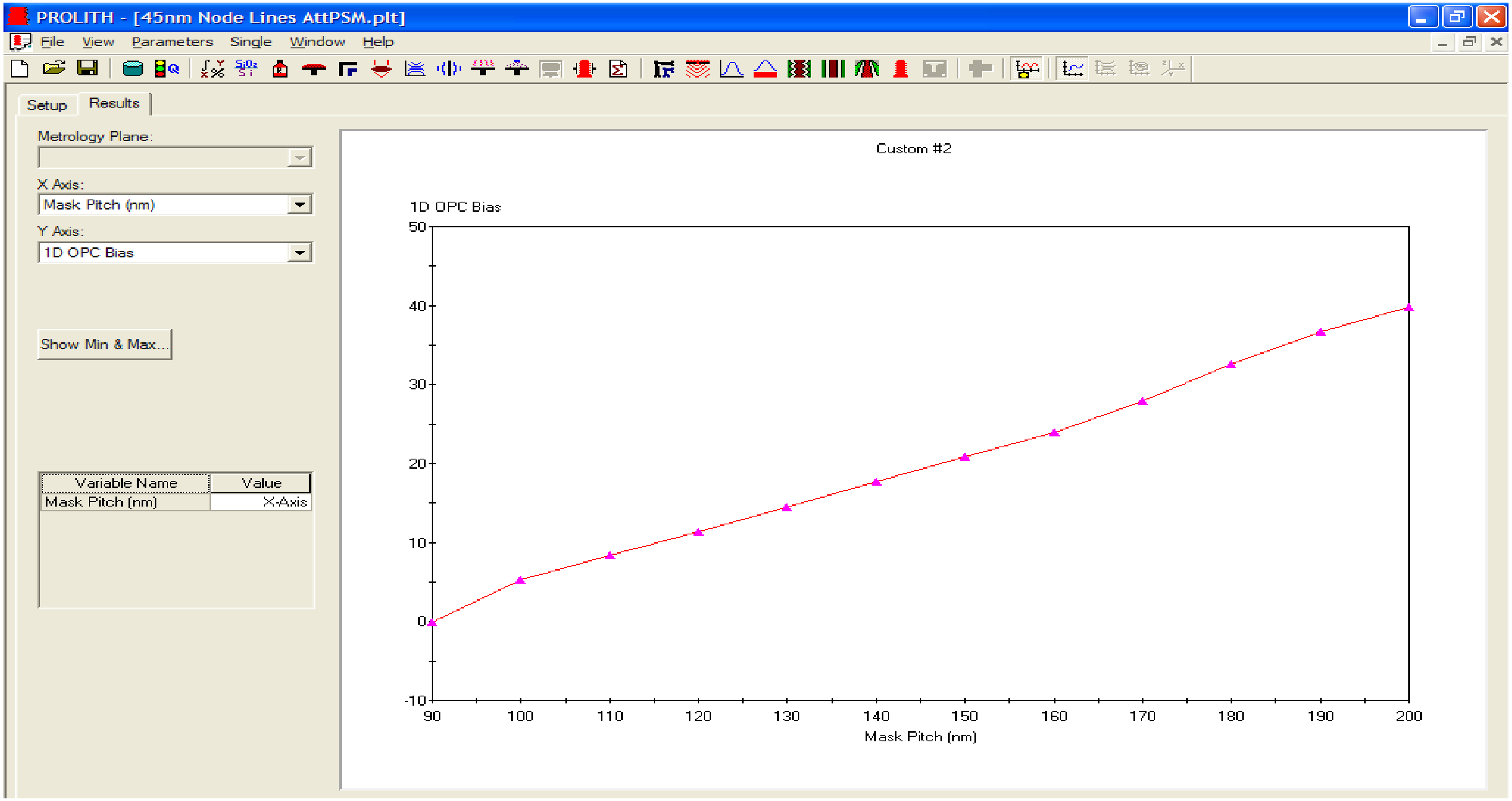
Simulation Set Name: Custom #1

☑ Generate Unique Name

Simulation Set

Bias Output

Simulation Set – Results



PROLITH - [45nm Node Lines AttPSM.plt]

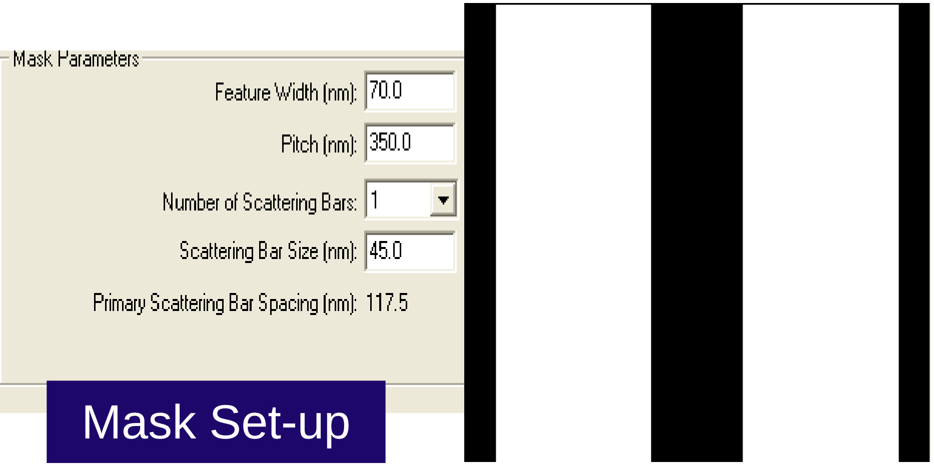
Metrology Plane:

X Axis: Mask Pitch (nm)

Y Axis: 1D OPC Bias

Variable Name	Value
Mask Pitch (nm)	X-Axis

Example – 1D Line with Assist Features



Mask Parameters

Feature Width (nm): 70.0

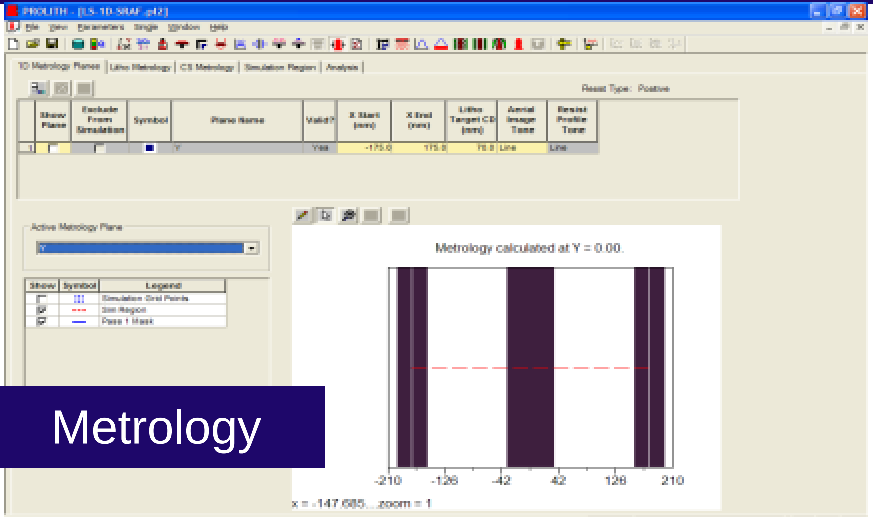
Pitch (nm): 350.0

Number of Scattering Bars: 1

Scattering Bar Size (nm): 45.0

Primary Scattering Bar Spacing (nm): 117.5

Mask Set-up



Resist Type: Positive

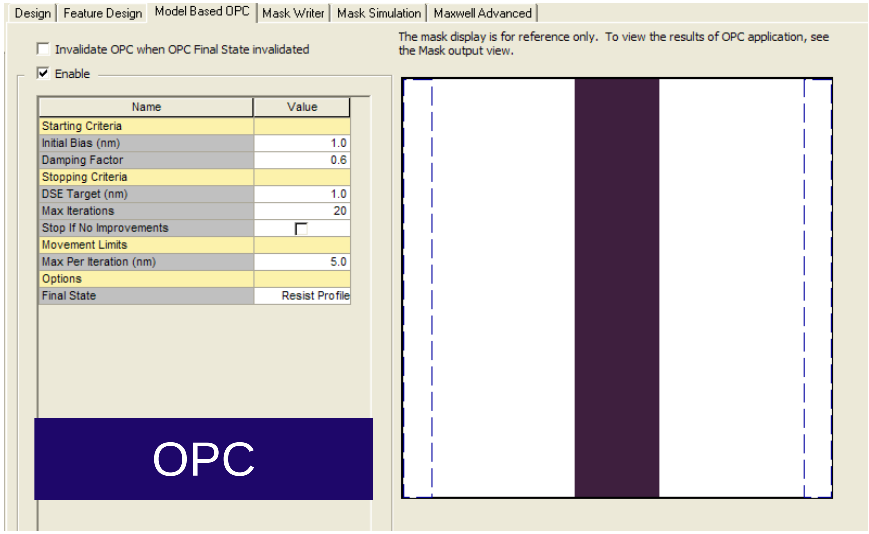
	Show Plane	Exclude From Simulation	Symbol	Plane Name	Valid?	X Start (nm)	X End (nm)	Litho Target CD (nm)	Aerial Image Tone	Resist Profile Tone
1	☐	☐	■	Y	Yes	-175.0	175.0	70.0	Line	Line

Show	Symbol	Legend
☐	⋮	Simulation Grid Points
☑	---	Sim Region
☑	—	Pass 1 Mask

Metrology calculated at Y = 0.00.

x = -147.685... zoom = 1

Metrology



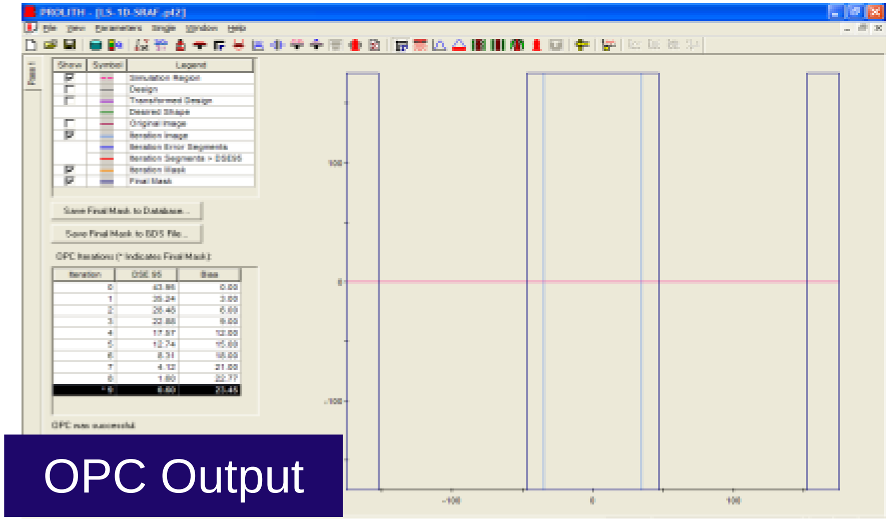
☐ Invalidate OPC when OPC Final State invalidated

☑ Enable

The mask display is for reference only. To view the results of OPC application, see the Mask output view.

Name	Value
Starting Criteria	
Initial Bias (nm)	1.0
Damping Factor	0.6
Stopping Criteria	
DSE Target (nm)	1.0
Max Iterations	20
Stop If No Improvements	☐
Movement Limits	
Max Per Iteration (nm)	5.0
Options	
Final State	Resist Profile

OPC



Show	Symbol	Legend
☑	---	Simulation Region
☐	—	Design
☐	—	Transformed Design
	—	Desired Shape
☐	—	Original Image
☑	—	Iteration Image
	—	Iteration Error Segments
	—	Iteration Segments > DSE95
☑	—	Iteration Mask
☑	—	Final Mask

Save Final Mask to Database...

Save Final Mask to GDS File...

OPC Iterations (* Indicates Final Mask):

Iteration	DSE 95	Bias
0	43.86	0.00
1	35.24	3.00
2	28.45	6.00
3	22.88	9.00
4	17.87	12.00
5	12.74	15.00
6	8.31	18.00
7	4.12	21.00
8	1.80	22.77
* 9	0.00	23.45

OPC was successful.

OPC Output

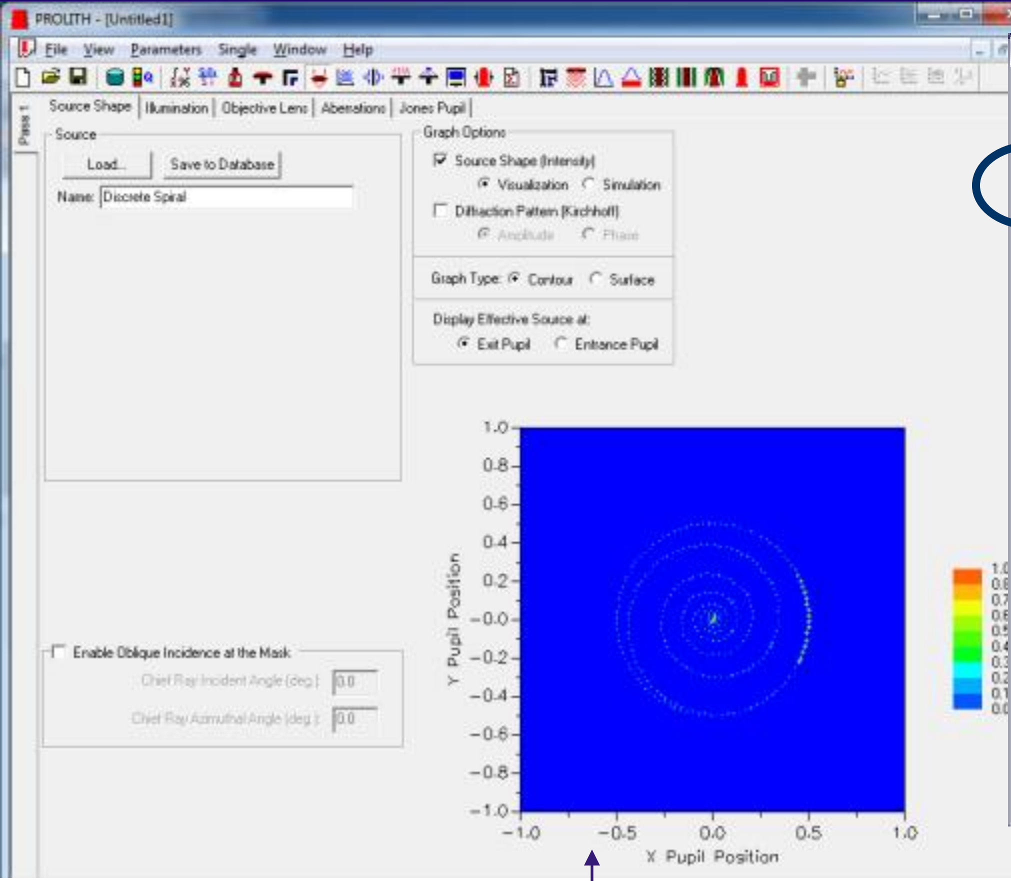
PPI Command

- Retrieve bias for single run simulation
  - GetOPCSingleRunBias()

- Retrieve bias for simulation set
  - GetOPCSimSetBias (SimSetIndex)

Imaging Tool Updates

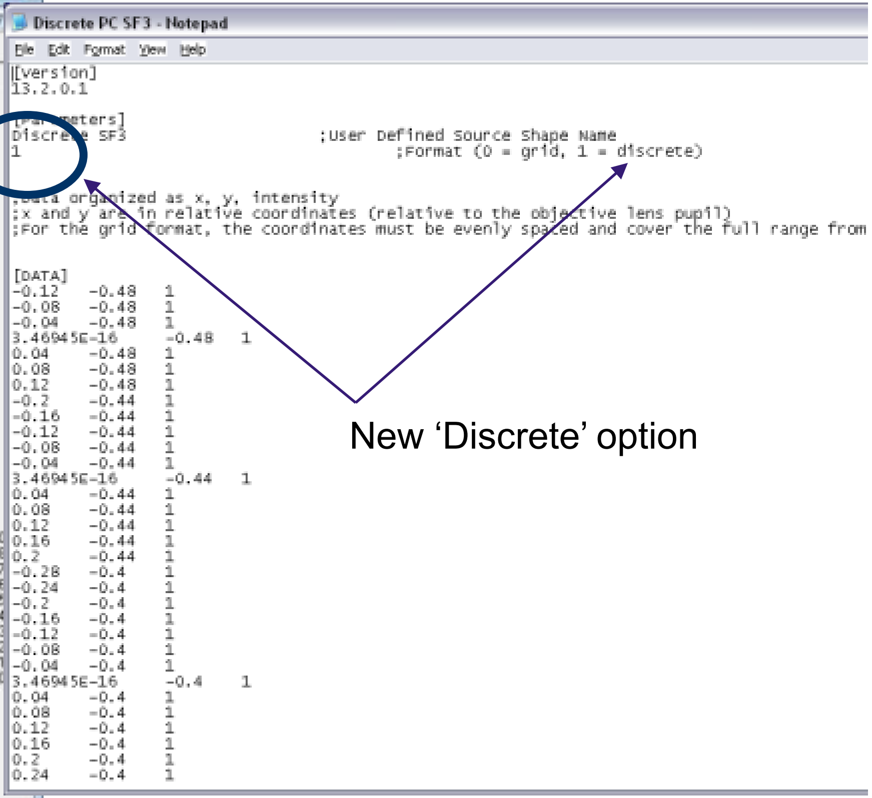
Sparse Source Shape in X3.1.1



Name: Discrete Spiral

☑ Source Shape (Intensity)
● Visualization ○ Simulation
☐ Diffraction Pattern (Kirchhoff)
● Amplitude ○ Phase
Graph Type: ● Contour ○ Surface
Display Effective Source at:
● Exit Pupil ○ Entrance Pupil

☐ Enable Oblique Incidence at the Mask
Chief Ray Incident Angle (deg.): 0.0
Chief Ray Azimuthal Angle (deg.): 0.0



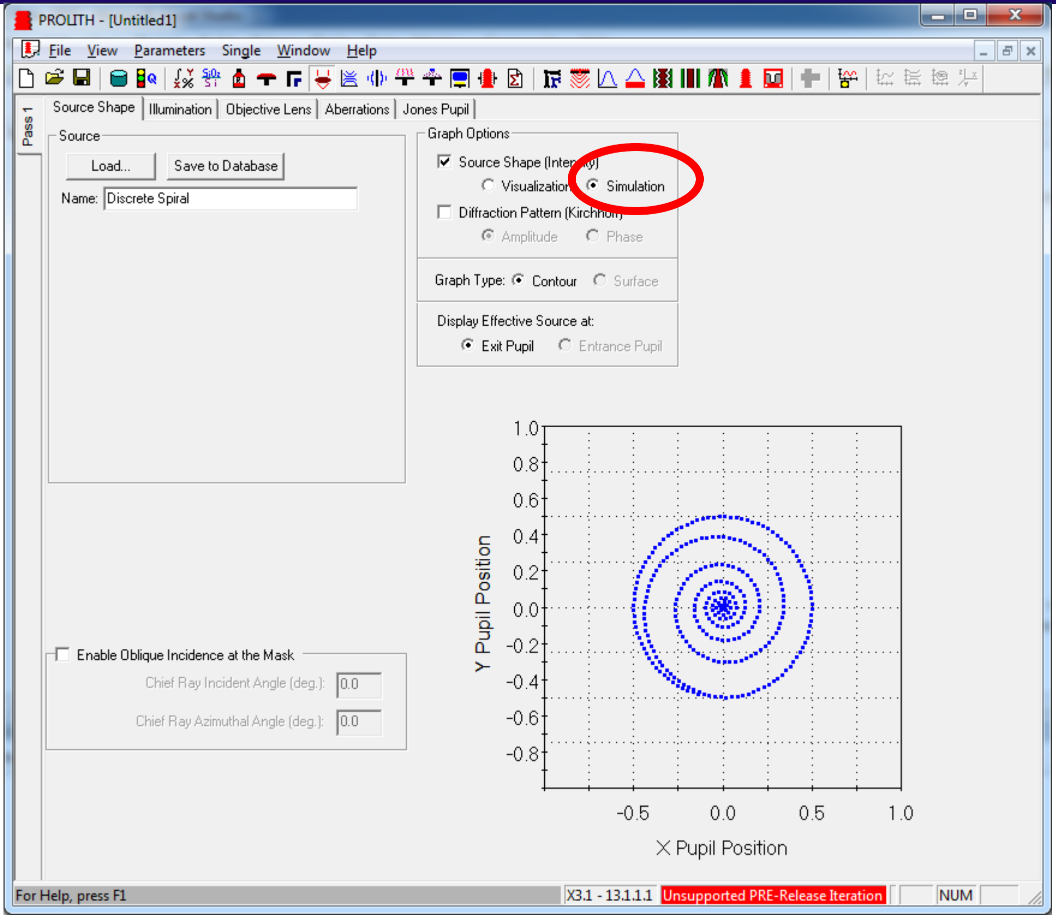
```
[version]
13.2.0.1

[Parameters]
Discrete SF3                    ;User Defined Source Shape Name
1                                      ;Format (0 = grid, 1 = discrete)


;Data organized as x, y, intensity
;x and y are in relative coordinates (relative to the objective lens pupil)
;For the grid format, the coordinates must be evenly spaced and cover the full range from


[DATA]
-0.12   -0.48   1
-0.08   -0.48   1
-0.04   -0.48   1
3.46945E-16     -0.48   1
0.04    -0.48   1
0.08    -0.48   1
0.12    -0.48   1
-0.2    -0.44   1
-0.16   -0.44   1
-0.12   -0.44   1
-0.08   -0.44   1
-0.04   -0.44   1
3.46945E-16     -0.44   1
0.04    -0.44   1
0.08    -0.44   1
0.12    -0.44   1
0.16    -0.44   1
0.2     -0.44   1
-0.28   -0.4    1
-0.24   -0.4    1
-0.2    -0.4    1
-0.16   -0.4    1
-0.12   -0.4    1
-0.08   -0.4    1
-0.04   -0.4    1
3.46945E-16     -0.4    1
0.04    -0.4    1
0.08    -0.4    1
0.12    -0.4    1
0.16    -0.4    1
0.2     -0.4    1
0.24    -0.4    1
```

New ‘Discrete’ option

Points are very sparse so Contour plot is has snapping issues (See next page)

Sparse Source shape in X3.1.1

New Plot when “Simulation” is Selected



Name: Discrete Spiral

☑ Source Shape (Intensity)
○ Visualization ● Simulation

☐ Diffraction Pattern (Kirchhoff)
● Amplitude ○ Phase

Graph Type: ● Contour ○ Surface

Display Effective Source at:
● Exit Pupil ○ Entrance Pupil

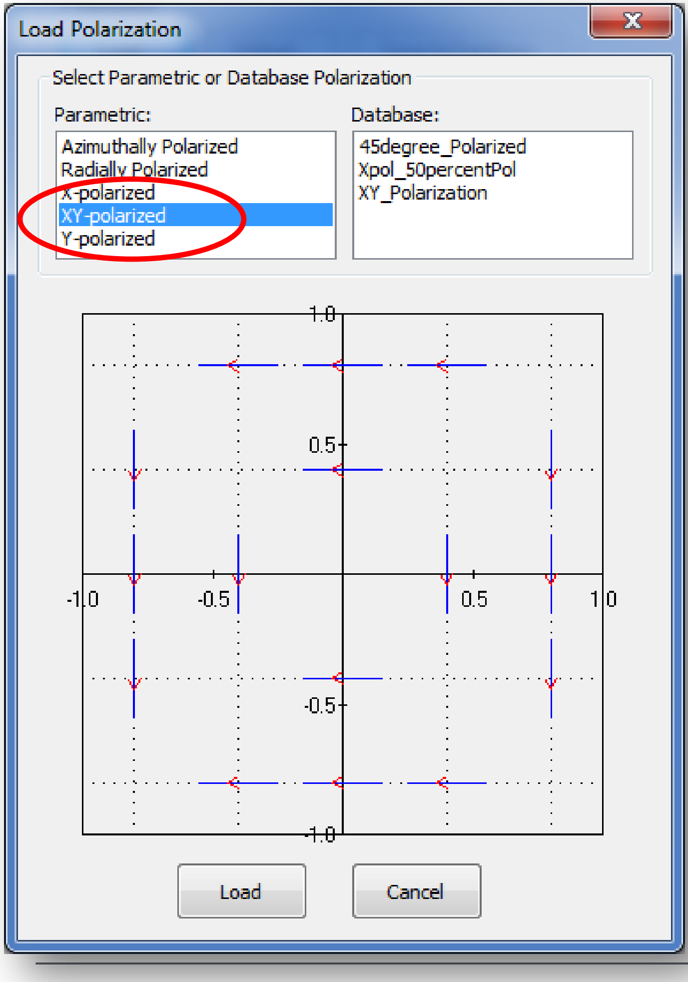
☐ Enable Oblique Incidence at the Mask
Chief Ray Incident Angle (deg.): 0.0
Chief Ray Azimuthal Angle (deg.): 0.0

For Help, press F1 | X3.1 - 13.1.1.1 | Unsupported PRE-Release Iteration | NUM

- When “simulation” radio button is selected, discrete source shapes are shown with an XY scatter plot. This eliminates the “snapping” errors in the contour plot.

New option for Polarization

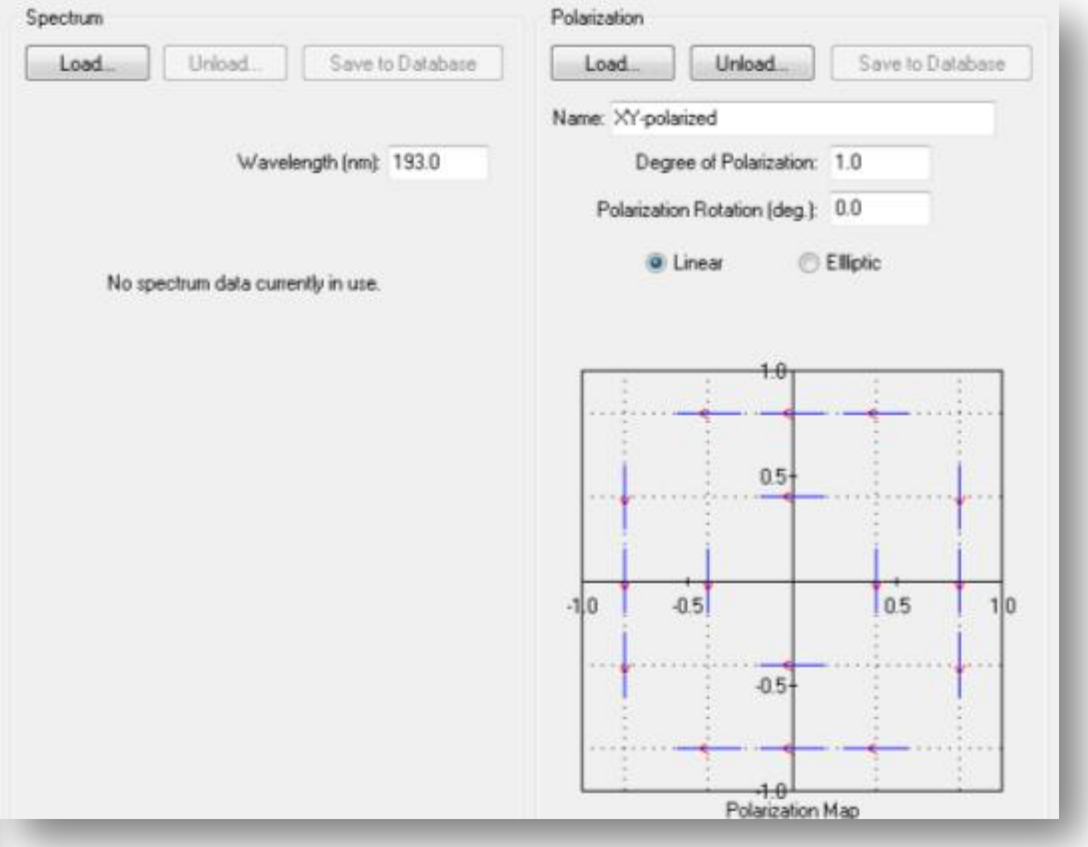
- Parametric XY polarization added to the current list



Select Parametric or Database Polarization

Parametric:
- Azimuthally Polarized
- Radially Polarized
- X-polarized
- XY-polarized
- Y-polarized

Database:
- 45degree_Polarized
- Xpol_50percentPol
- XY_Polarization



Wavelength (nm): 193.0

No spectrum data currently in use.

Name: XY-polarized

Degree of Polarization: 1.0

Polarization Rotation (deg.): 0.0

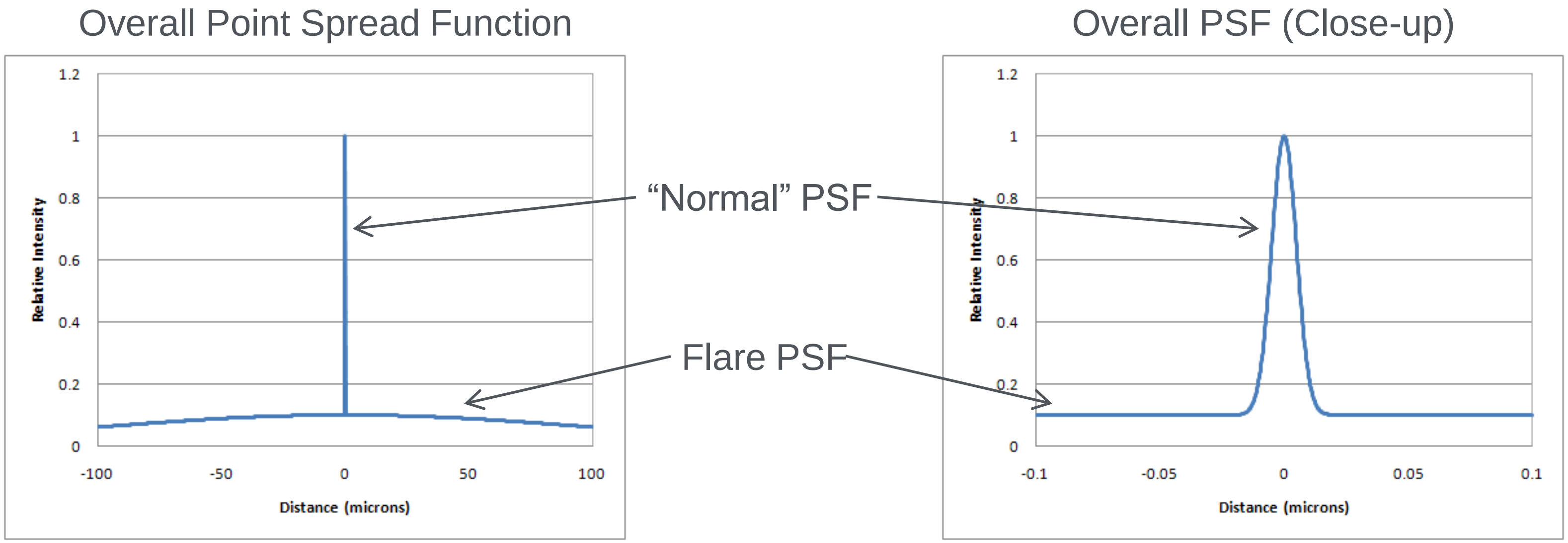
● Linear ○ Elliptic

What is flare?

(Source: wikipedia.org entry for “flare”)

- Flare is the long range “halo” shown in the picture.
- Flare level is proportional to the intensity at each point in the image without flare.
- Halo is present at every point in the image, but we only notice the part near the sun because it is the brightest point in the image.
- How do we simulate this effect in lithography?

Imaging Point-Spread Functions



"Normal" PSF

Flare PSF

- Image is calculated in two steps:
  - First part is imaging without flare. This image has very high resolution, and is a "normal PROLITH calculation." The Point Spread Function (PSF) for this part is very narrow (a few nanometers).
  - Second part of calculation adds flare. The Flare PSF is the same as the "halo" on the previous slide. The Flare PSF can be very long-range (several millimeters).

Basic Flare Equation – Starting Point

$$I_{\text{total}}(\mathbf{r}) = (1 - TIS - DC) I_{\text{ideal}}(\mathbf{r}) + PSF(\mathbf{r}) \otimes I_{\text{ideal}}(\mathbf{r}) + DC \cdot I_{average}$$

where

$TIS = Total\ \ Integrated\ \ Scatter$

$DC = DC\,like\ long\ \ range\ \ flare$

$I_{average} = Average\ over\ entire\ \ field$

- Basic inputs are *Flare* PSF, DC term, as well as pattern density information outside of the PROLITH mask region.
- This model is taken from the paper “Evaluation of stray light and quantitative analysis of its impact on lithography” by Kim, De Bisschop, and Vandenberghe in JM3 (2005). (Also very similar to the model by Stearns et al. in Journal of Applied Physics, 1998).
- DC-like term is similar to equation from Chris Mack (SPIE 2003)

PSF Flare – Inputs & Outputs

- Inputs
  - Flare Point Spread Function
    - Parametric
      - DC, Gaussian, Fractal, Double Fractal
    - Database
  - Pattern density (“flare context”)
    - Parametric – Uniform
    - Database – ASCII file format
- Outputs
  - Modified aerial image and image in resist

Inputs for Flare PSF – database and parametric

- Database – two columns of data: distance and stray light.

- Parametric – fractal, double fractal, and Gaussian

$$Fractal = \begin{cases} \dfrac{K}{r^{n+1}} & for\ r > r_{\min} \\ 0 & for\ r \le r_{\min} \end{cases}$$

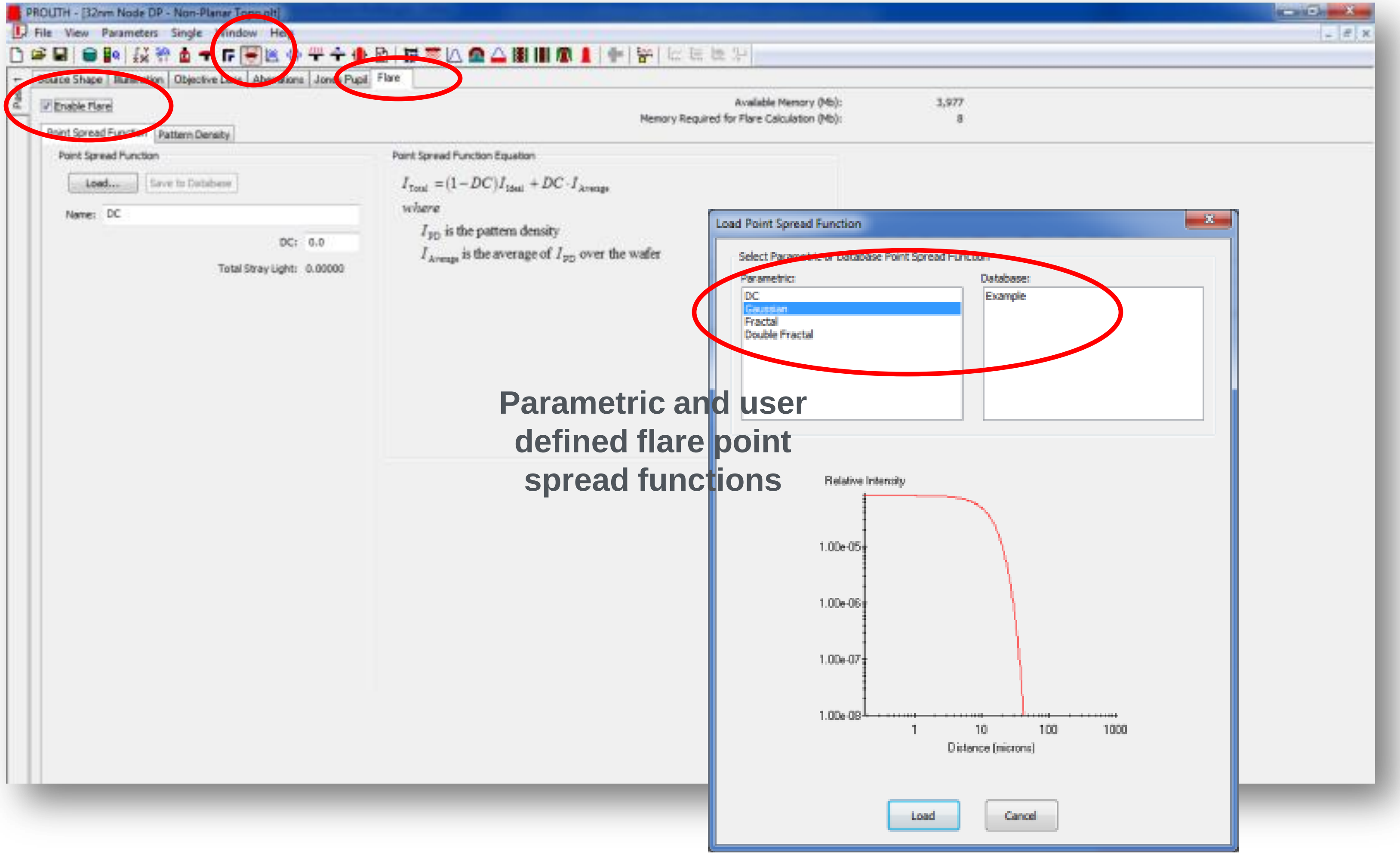
$$Gaussian = \begin{cases} K \exp\left(-\dfrac{r^2}{2\sigma^2}\right) & for\ r > r_{\min} \\ 0 & for\ r \le r_{\min} \end{cases}$$

$$Double\ Fractal = \begin{cases} \dfrac{K_1}{r^{n_1+1}} + \dfrac{K_2}{r^{n_2+1}} & for\ r > r_{\min} \\ 0 & for\ r \le r_{\min} \end{cases}$$

  - Spectral index (n) and σ are straightforward inputs in PROLITH GUI
  - Input of amplitude (K) is through TIS (total integrated scatter) – this is the total amount of flare for an open-frame exposure .

Flare as new Tab on Imaging Tool Window

Imaging Tool



PROLITH - [32nm Node DP - Non-Planar Topo.plt]

☑ Enable Flare

Available Memory (Mb): 3,977

Memory Required for Flare Calculation (Mb): 8

Point Spread Function

Name: DC

DC: 0.0

Total Stray Light: 0.00000

Point Spread Function Equation

$$I_{Total} = (1 - DC) I_{Ideal} + DC \cdot I_{Average}$$

where

I_{PD} is the pattern density

$I_{Average}$ is the average of I_{PD} over the wafer

Load Point Spread Function

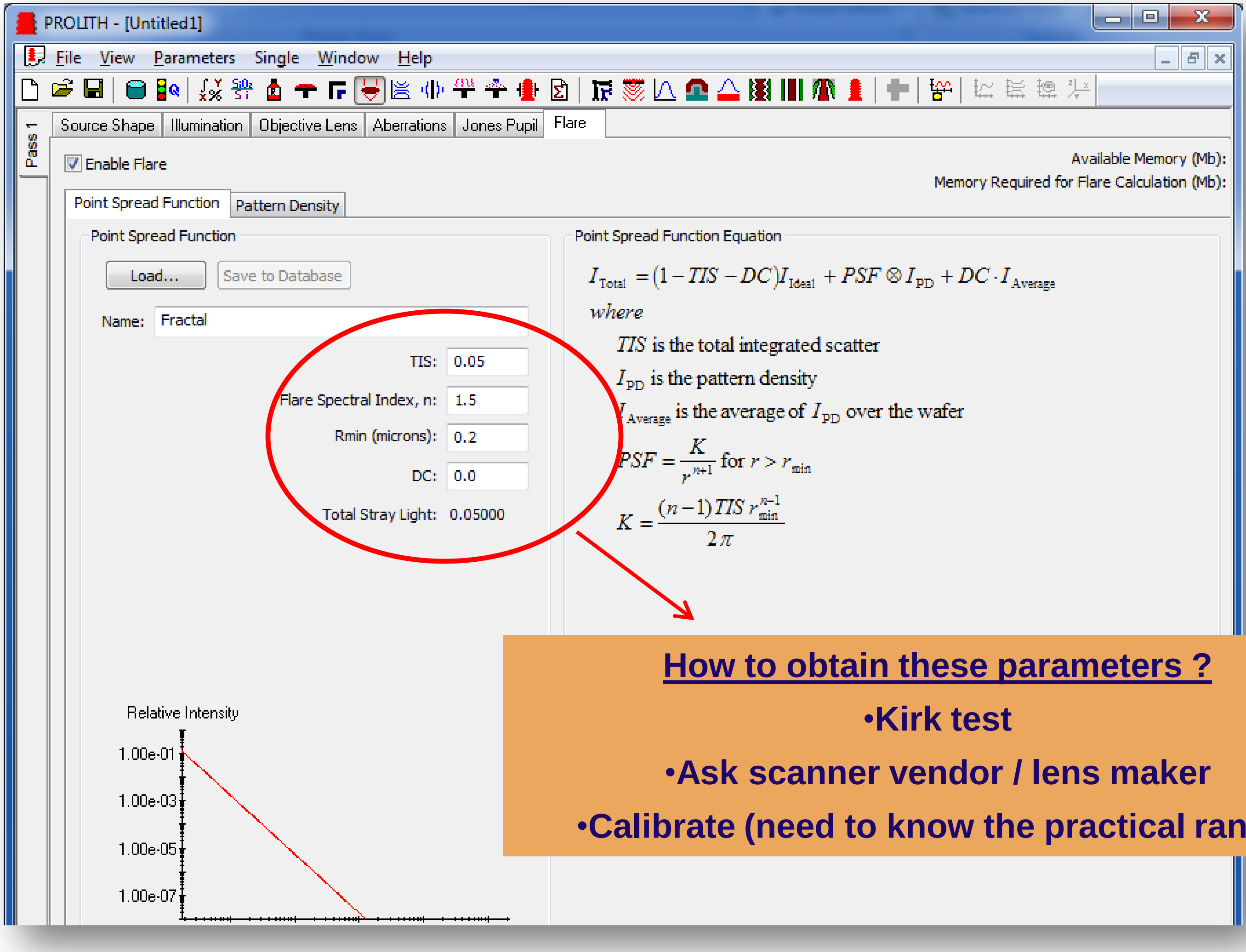
Select Parametric or Database Point Spread Function

Parametric:
- DC
- Gaussian
- Fractal
- Double Fractal

Database:
- Example

Parametric and user defined flare point spread functions

Fractal PSF



☑ Enable Flare

Available Memory (Mb):

Memory Required for Flare Calculation (Mb):

Point Spread Function

Name: Fractal

TIS: 0.05

Flare Spectral Index, n: 1.5

Rmin (microns): 0.2

DC: 0.0

Total Stray Light: 0.05000

Point Spread Function Equation

$$I_{Total} = (1 - TIS - DC) I_{Ideal} + PSF \otimes I_{PD} + DC \cdot I_{Average}$$

where

TIS is the total integrated scatter

I_{PD} is the pattern density

$I_{Average}$ is the average of I_{PD} over the wafer

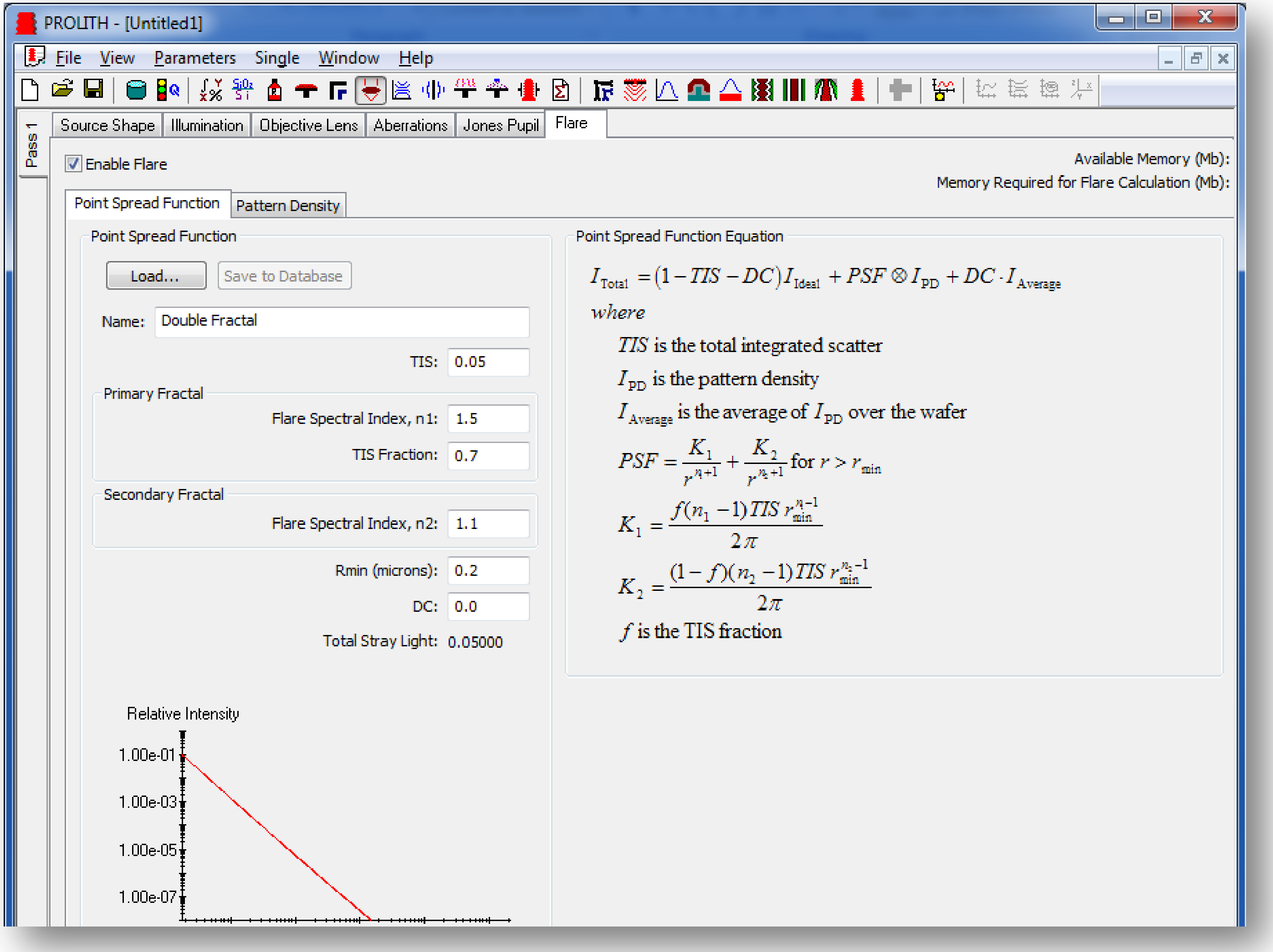
$$PSF = \frac{K}{r^{n+1}} \text{ for } r > r_{min}$$

$$K = \frac{(n-1)\, TIS\, r_{min}^{n-1}}{2\pi}$$

How to obtain these parameters ?

- **Kirk test**
- **Ask scanner vendor / lens maker**
- **Calibrate (need to know the practical range)**

Double Fractal PSF



☑ Enable Flare

Available Memory (Mb):

Memory Required for Flare Calculation (Mb):

Point Spread Function

Name: Double Fractal

TIS: 0.05

Primary Fractal

Flare Spectral Index, n1: 1.5

TIS Fraction: 0.7

Secondary Fractal

Flare Spectral Index, n2: 1.1

Rmin (microns): 0.2

DC: 0.0

Total Stray Light: 0.05000

Point Spread Function Equation

$$I_{\text{Total}} = (1 - TIS - DC)\, I_{\text{Ideal}} + PSF \otimes I_{PD} + DC \cdot I_{\text{Average}}$$

where

TIS is the total integrated scatter

I_{PD} is the pattern density

I_{Average} is the average of I_{PD} over the wafer

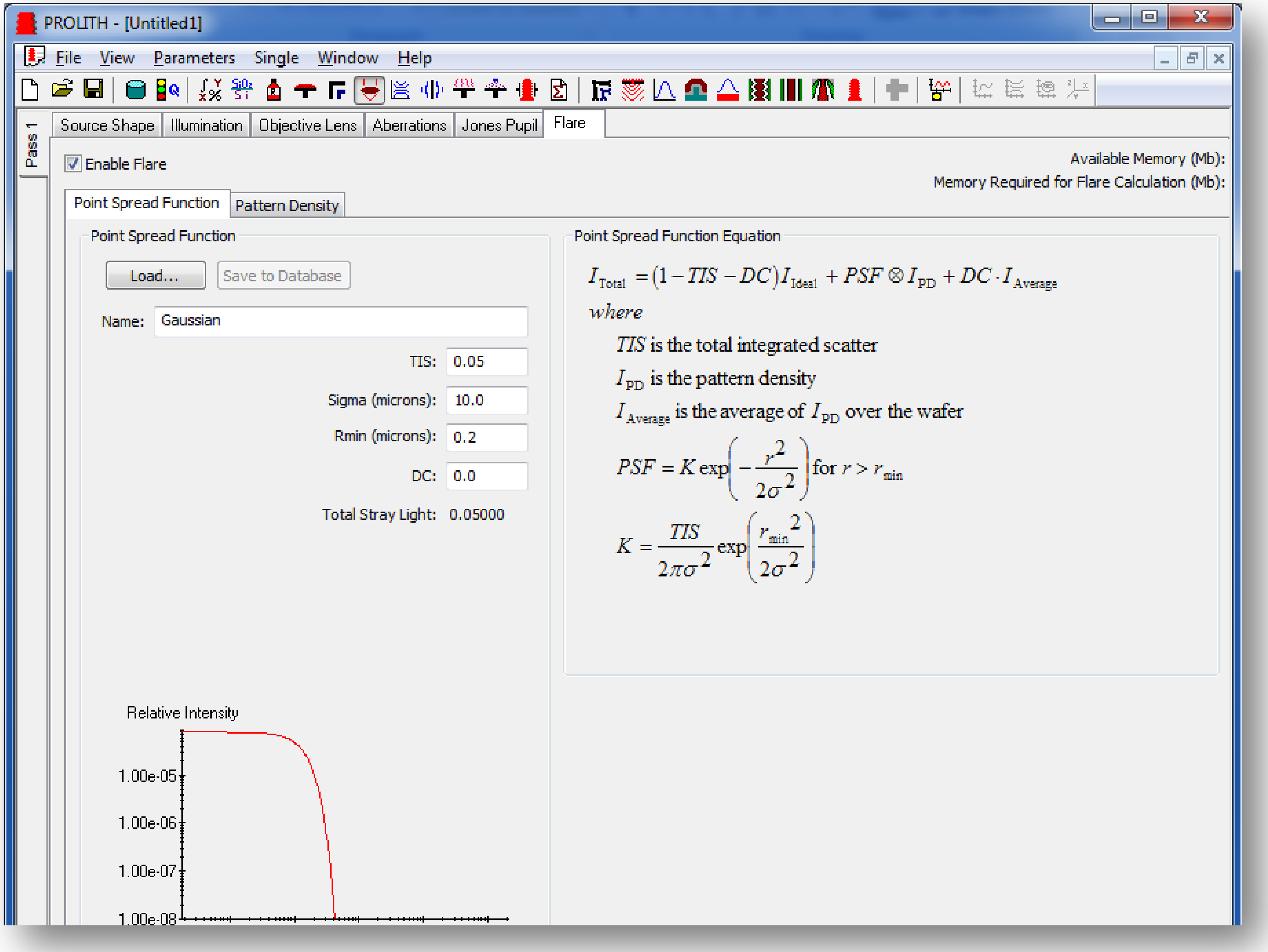
$$PSF = \frac{K_1}{r^{n_1+1}} + \frac{K_2}{r^{n_2+1}} \text{ for } r > r_{\min}$$

$$K_1 = \frac{f(n_1 - 1)\, TIS\, r_{\min}^{n_1-1}}{2\pi}$$

$$K_2 = \frac{(1-f)(n_2 - 1)\, TIS\, r_{\min}^{n_2-1}}{2\pi}$$

f is the TIS fraction

Gaussian PSF



☑ Enable Flare

Name: Gaussian

TIS: 0.05

Sigma (microns): 10.0

Rmin (microns): 0.2

DC: 0.0

Total Stray Light: 0.05000

$$I_{\text{Total}} = (1 - TIS - DC) I_{\text{Ideal}} + PSF \otimes I_{\text{PD}} + DC \cdot I_{\text{Average}}$$

where

TIS is the total integrated scatter

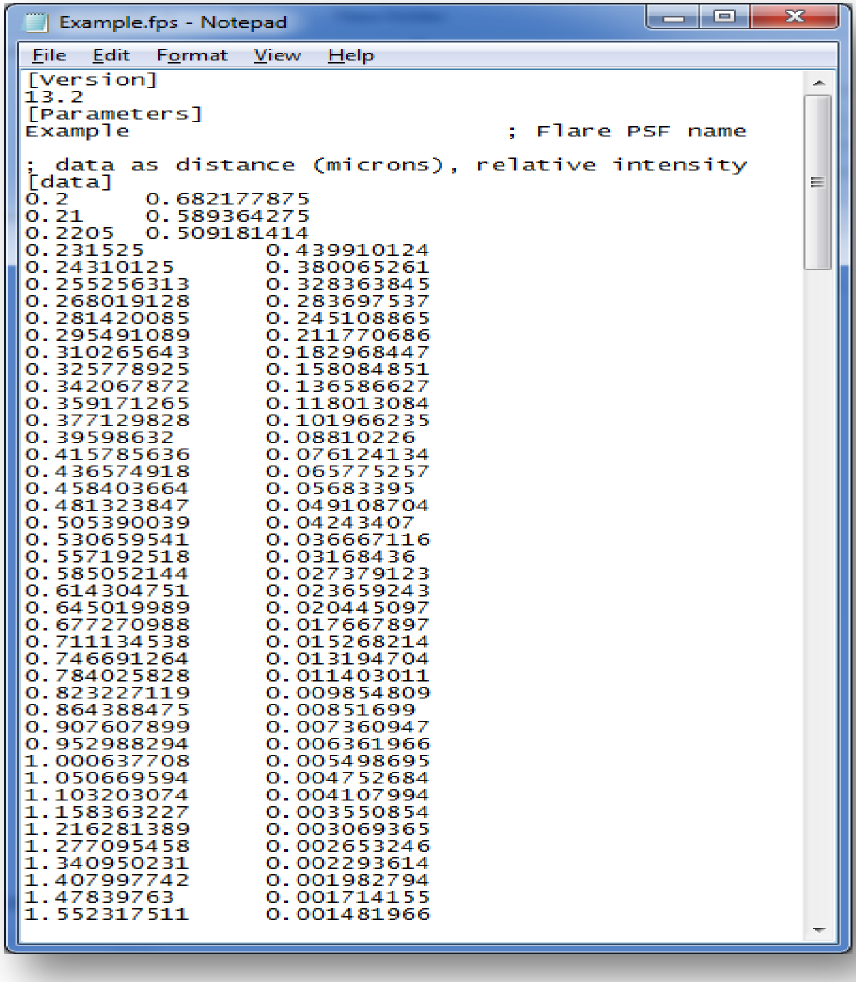
I_{PD} is the pattern density

I_{Average} is the average of I_{PD} over the wafer

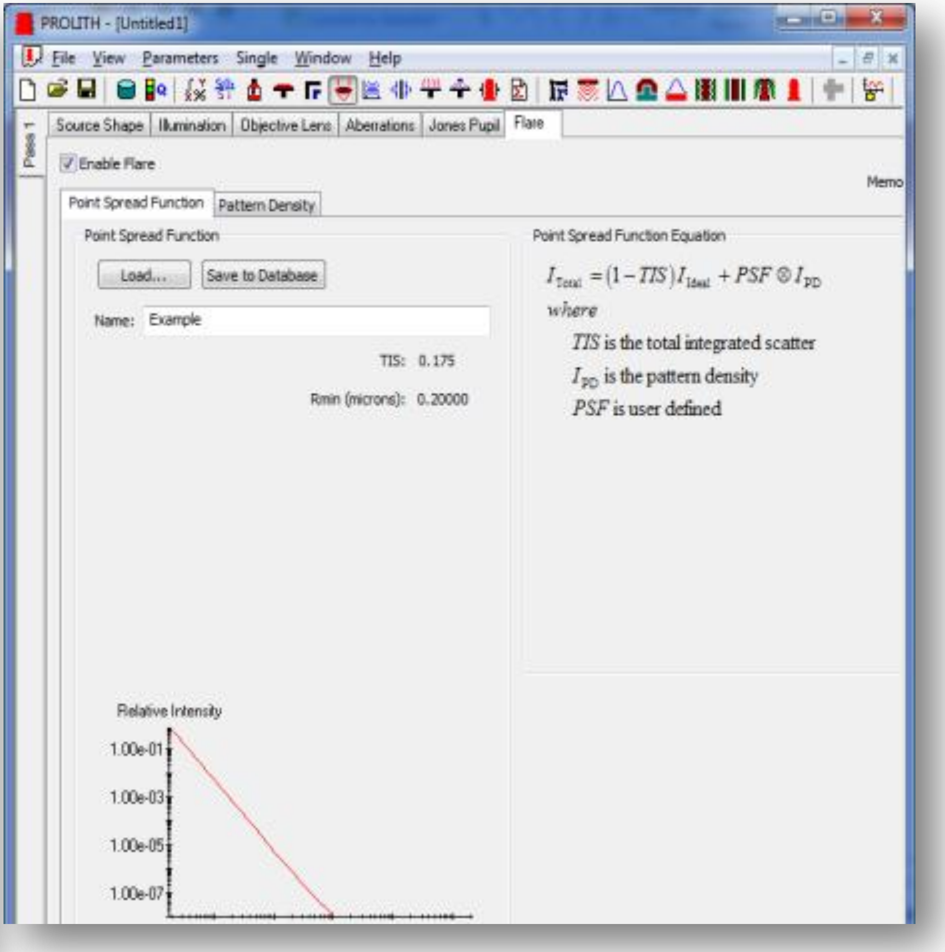
$$PSF = K \exp\left(-\frac{r^2}{2\sigma^2}\right) \text{ for } r > r_{\min}$$

$$K = \frac{TIS}{2\pi\sigma^2} \exp\left(\frac{r_{\min}^2}{2\sigma^2}\right)$$

Database PSF



```
[Version]
13.2
[Parameters]
Example                                ; Flare PSF name

; data as distance (microns), relative intensity
[data]
0.2       0.682177875
0.21      0.589364275
0.2205    0.509181414
0.231525            0.439910124
0.24310125          0.380065261
0.255256313         0.328363845
0.268019128         0.283697537
0.281420085         0.245108865
0.295491089         0.211770686
0.310265643         0.182968447
0.325778925         0.158084851
0.342067872         0.136586627
0.359171265         0.118013084
0.377129828         0.101966235
0.39598632          0.08810226
0.415785636         0.076124134
0.436574918         0.065775257
0.458403664         0.05683395
0.481323847         0.049108704
0.505390039         0.04243407
0.530659541         0.036667116
0.557192518         0.03168436
0.585052144         0.027379123
0.614304751         0.023659243
0.645019989         0.020445097
0.677270988         0.017667897
0.711134538         0.015268214
0.746691264         0.013194704
0.784025828         0.011403011
0.823227119         0.009854809
0.864388475         0.00851699
0.907607899         0.007360947
0.952988294         0.006361966
1.000637708         0.005498695
1.050669594         0.004752684
1.103203074         0.004107994
1.158363227         0.003550854
1.216281389         0.003069365
1.277095458         0.002653246
1.340950231         0.002293614
1.407997742         0.001982794
1.47839763          0.001714155
1.552317511         0.001481966
```



☑ Enable Flare

Point Spread Function

Name: Example

TIS: 0.175

Rmin (microns): 0.20000

Point Spread Function Equation

$$I_{Total} = (1 - TIS) I_{Ideal} + PSF \otimes I_{PD}$$

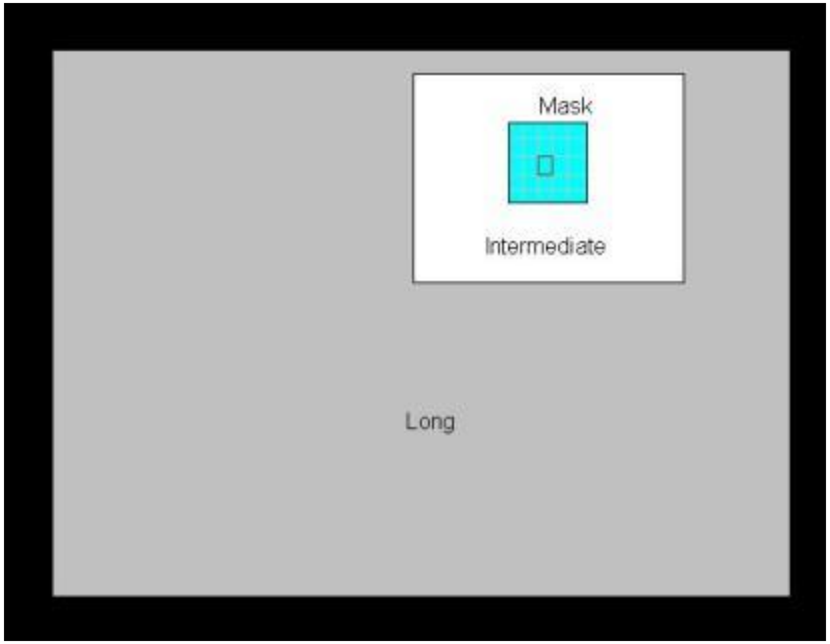
where

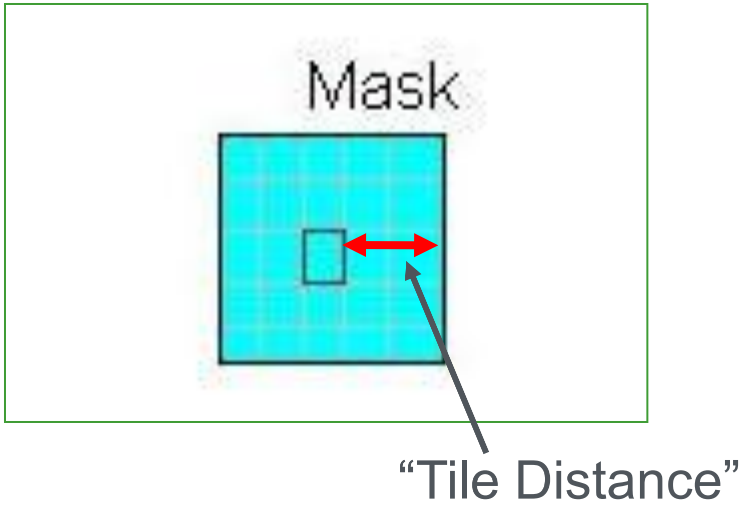
TIS is the total integrated scatter

I_{PD} is the pattern density

PSF is user defined

Long, Medium, and Short-range Mask Information

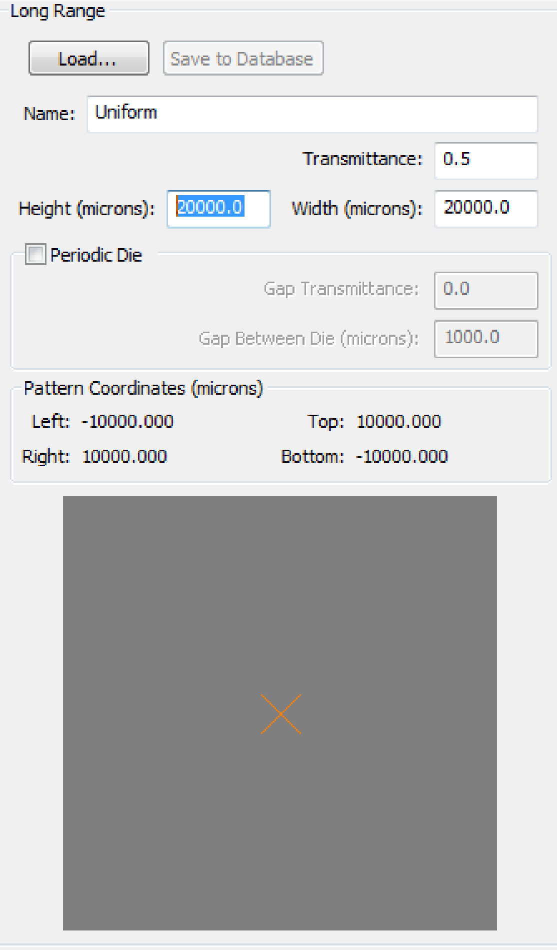




- Long range and medium range information comes from
  - Database – 2D array of intensity values
  - Parametric – rectangular region with transmittance
- Short range information is rigorous imaging calculation tiled out from the PROLITH mask region

Parametric Pattern Density - Uniform

- User can select parametric or database pattern density
- For long range and medium range user can choose Uniform pattern density:
  - User can specify the area
  - Same transmittance is applied to the entire region



Long Range

Name: Uniform

Transmittance: 0.5

Height (microns): 20000.0

Width (microns): 20000.0

☐ Periodic Die

Gap Transmittance: 0.0

Gap Between Die (microns): 1000.0

Pattern Coordinates (microns)

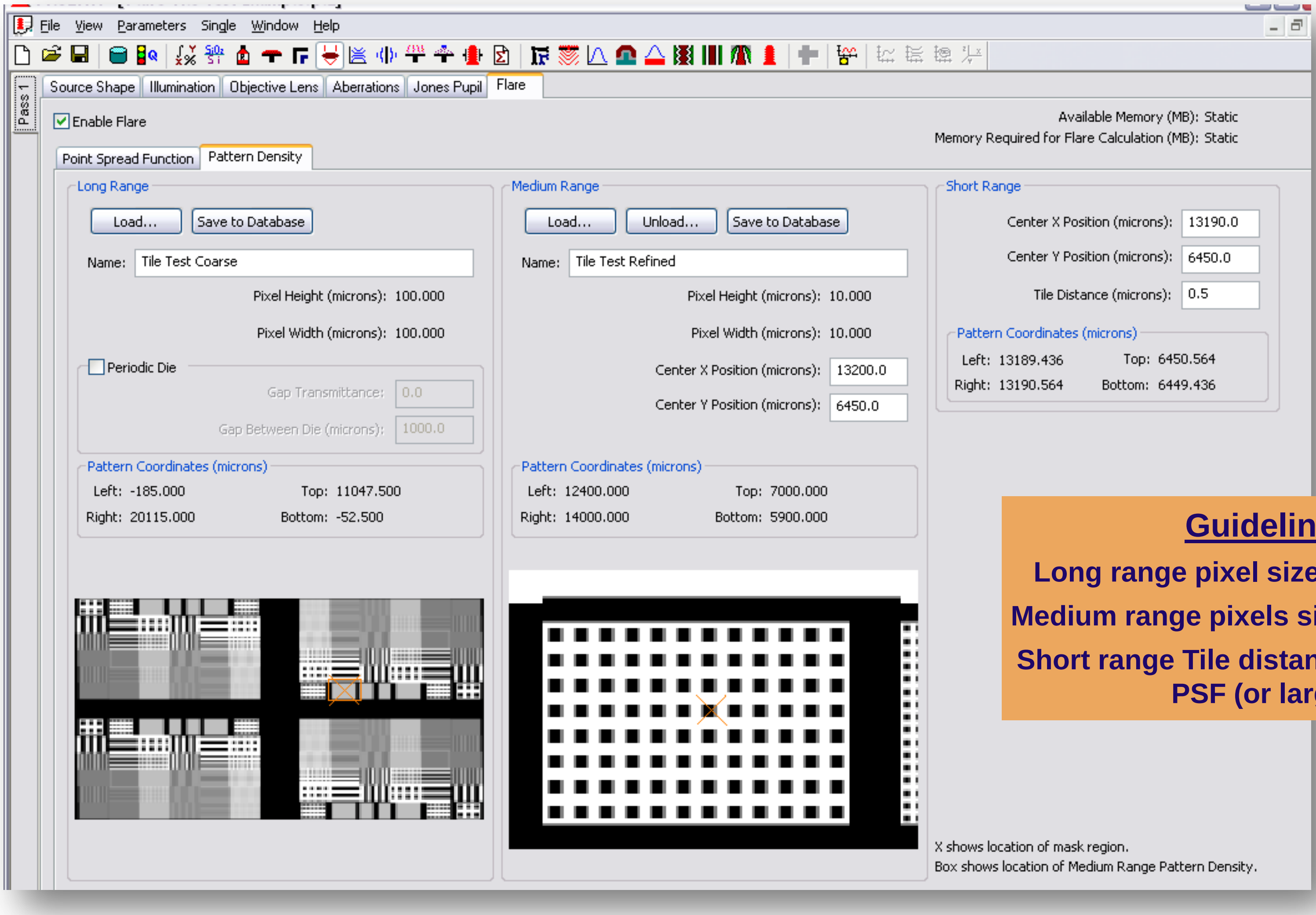
Left: -10000.000

Top: 10000.000

Right: 10000.000

Bottom: -10000.000

Database Pattern Density – User defined



☑ Enable Flare

Available Memory (MB): Static
Memory Required for Flare Calculation (MB): Static

Long Range

Name: Tile Test Coarse
Pixel Height (microns): 100.000
Pixel Width (microns): 100.000

☐ Periodic Die
Gap Transmittance: 0.0
Gap Between Die (microns): 1000.0

Pattern Coordinates (microns)

Left:	-185.000	Top:	11047.500
Right:	20115.000	Bottom:	-52.500

Medium Range

Name: Tile Test Refined
Pixel Height (microns): 10.000
Pixel Width (microns): 10.000
Center X Position (microns): 13200.0
Center Y Position (microns): 6450.0

Pattern Coordinates (microns)

Left:	12400.000	Top:	7000.000
Right:	14000.000	Bottom:	5900.000

Short Range

Center X Position (microns): 13190.0
Center Y Position (microns): 6450.0
Tile Distance (microns): 0.5

Pattern Coordinates (microns)

Left:	13189.436	Top:	6450.564
Right:	13190.564	Bottom:	6449.436

X shows location of mask region.
Box shows location of Medium Range Pattern Density.

Guidelines

Long range pixel size ~ 10 - 500 um

Medium range pixels size ~ 0.5 - 10 um

Short range Tile distance ~ 2 x r_{min} on PSF (or larger)

Database Pattern Density File Format

a) **Database Pattern Density File Format**

   i) A database pattern density will be available for long and medium range pattern densities.

   ii) The database entry will consist of:

      (1) The name of the pattern density.

      (2) The top, right, bottom, and left dimensions in microns.

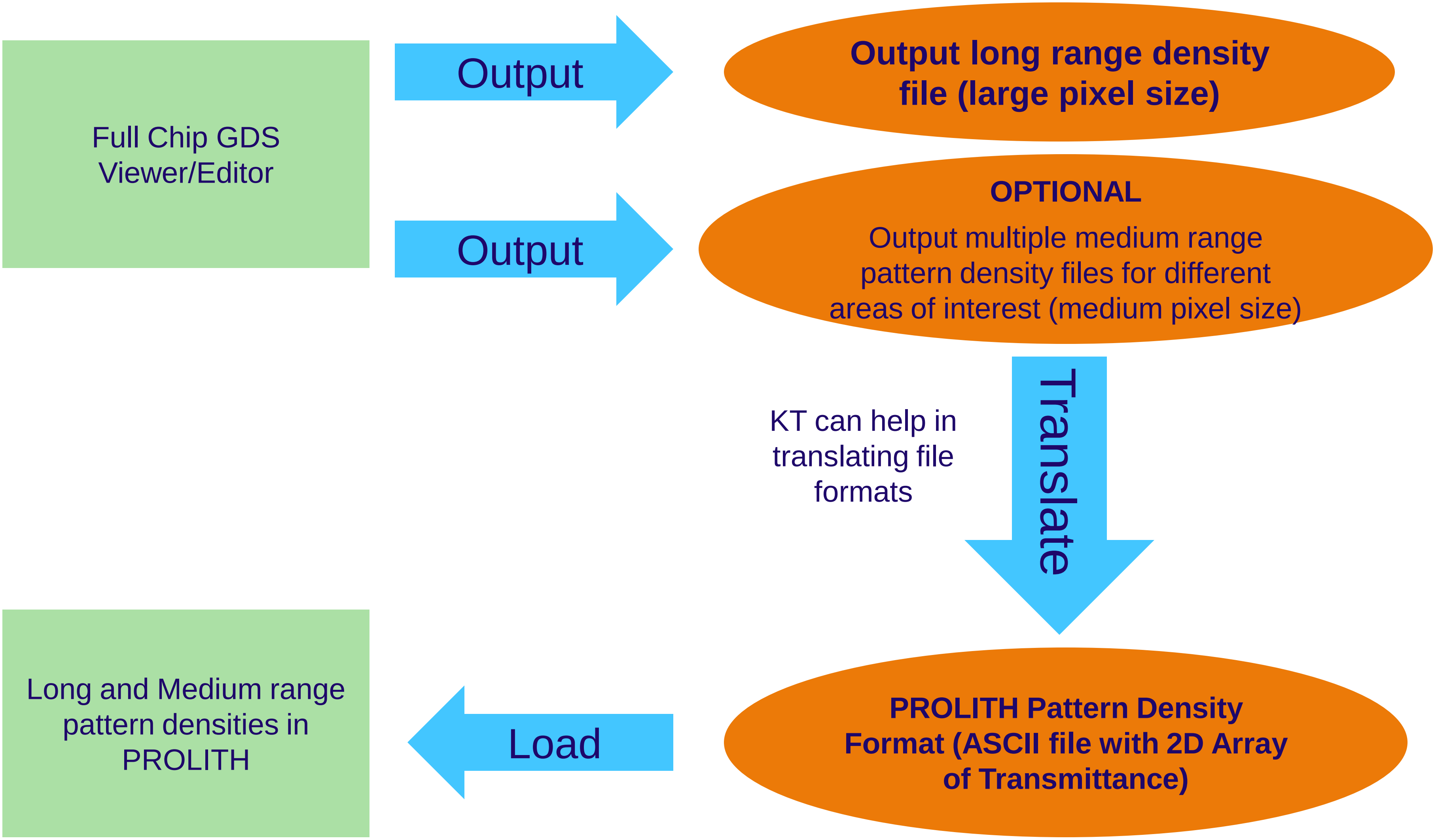
      (3) The number of rows and columns

      (4) A 2D array of transmittance values. Where the transmittance is between 0 and 1 (inclusive).

   iii) An example of the file:

```
[Version]
13.2.2.1

[Parameters]
Example Pattern Density                  ;Pattern Density name
130000, 120000, 100000, 100000           ;Pattern density dimensions [top,right,bottom,left](microns)
300, 200                                 ;Rows, columns

[Data]
0.04258 0.10708 0.10711 0.10746 0.1074 0.10826 0.10802 0.1064 0.10724 0.10585 0.03009 ...
0.04145 0.10718 0.10602 0.10767 0.10598 0.10519 0.10606 0.10656 0.10419 0.10633 0.02693 ...
```

Workflow to set-up pattern densities



Full Chip GDS Viewer/Editor

Output

Output long range density file (large pixel size)

Output

OPTIONAL

Output multiple medium range pattern density files for different areas of interest (medium pixel size)

Translate

KT can help in translating file formats

PROLITH Pattern Density Format (ASCII file with 2D Array of Transmittance)

Load

Long and Medium range pattern densities in PROLITH

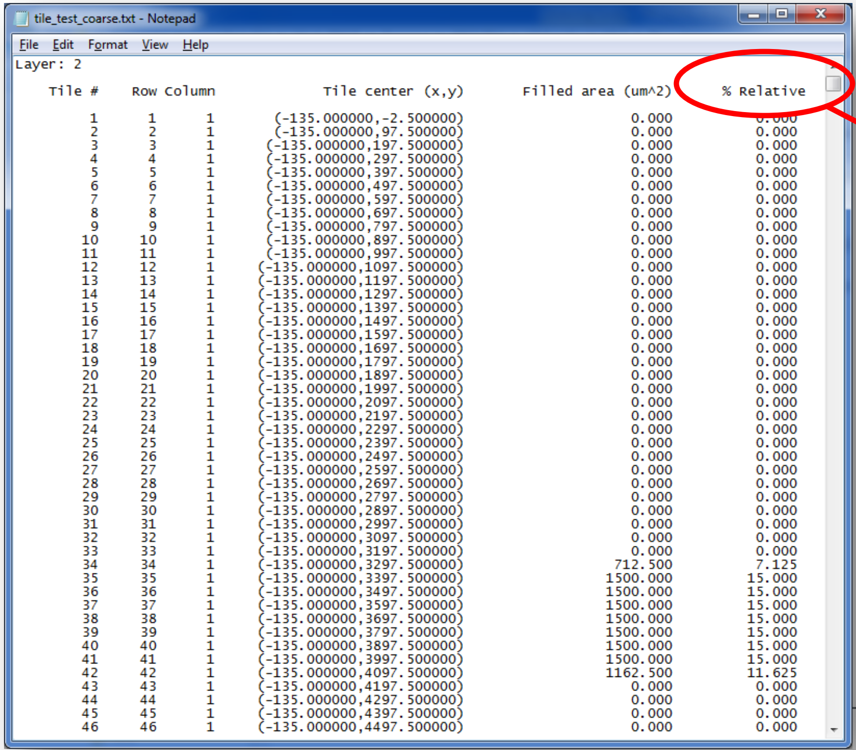
Example of pattern density file generation using QckVu and Areafill software from Artwork

- Command to generate coarse pattern density with 100 um x100 um pixel size

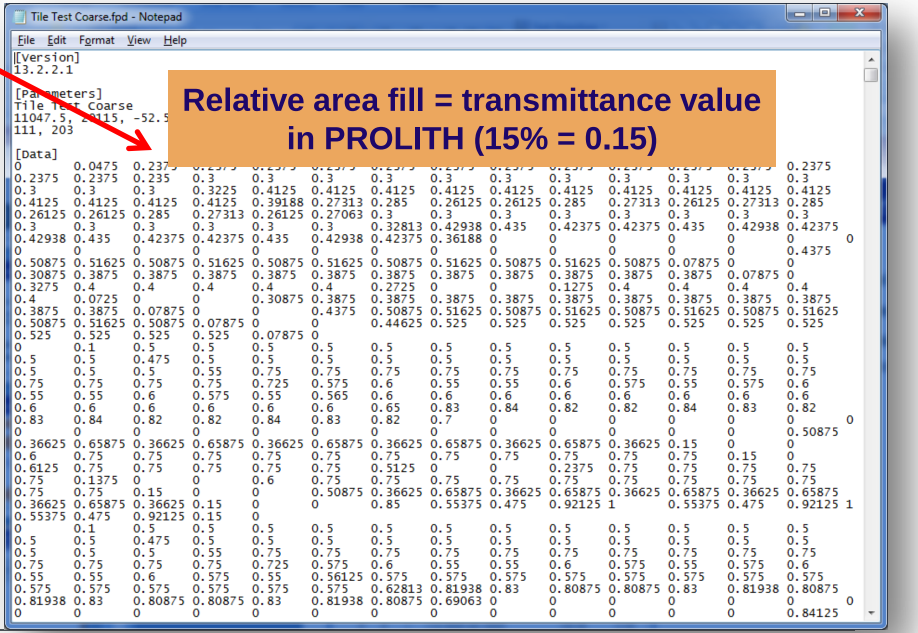
```
C:\WCAD\AreaFill\areafill.exe tiletest.gds tile_test_coarse.txt = +2 -tile:100,100
```

- Command to generate coarse pattern density with 10 um x 10 um pixel size

```
C:\WCAD\AreaFill\areafill.exe tiletest.gds tile_test_refined.txt = +2 -tile:10,10 -window:12400,5900,14000,7000
```



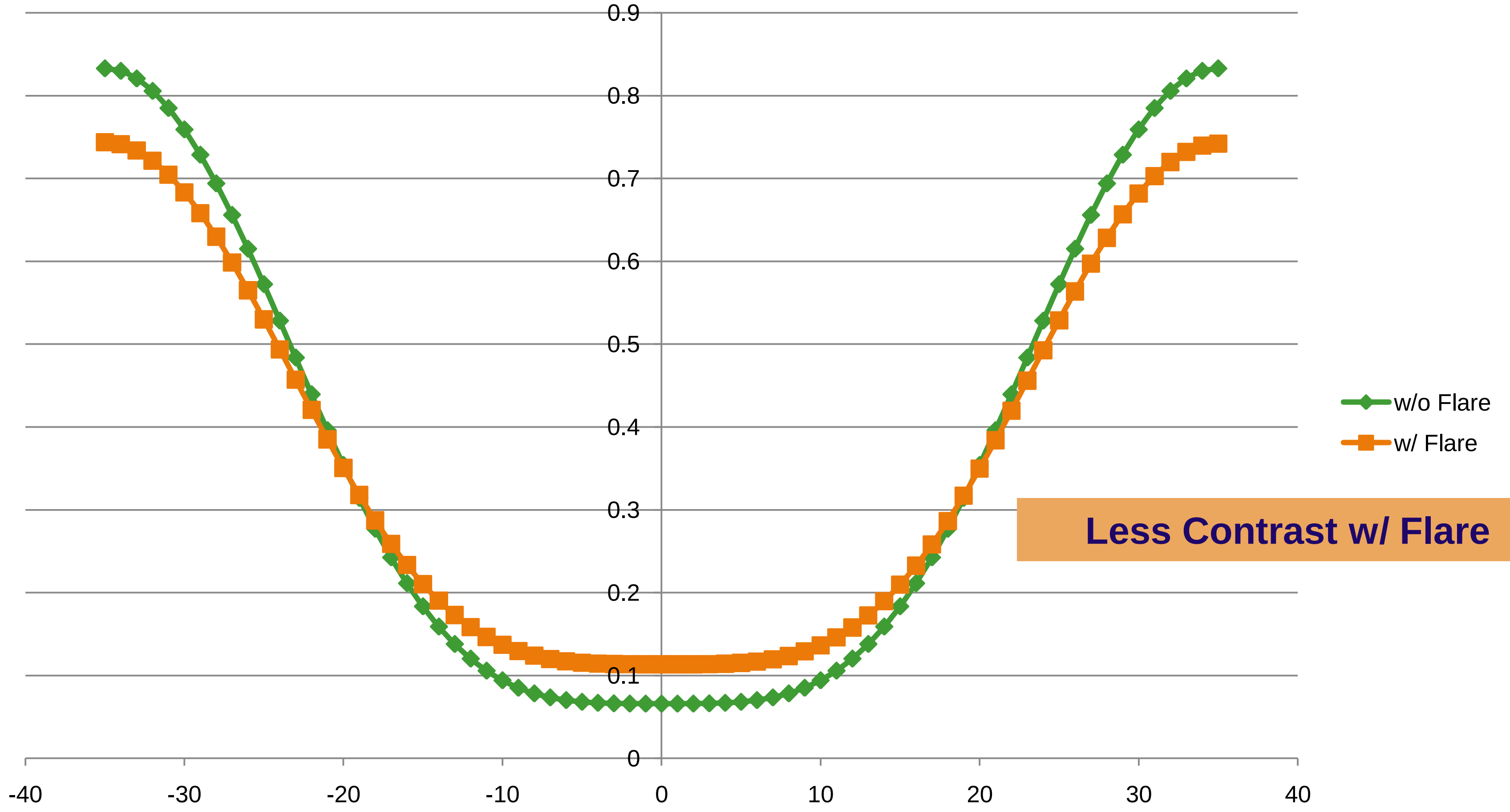
```
Layer: 2

   Tile #    Row Column          Tile center (x,y)        Filled area (um^2)     % Relative

        1      1      1     (-135.000000,-2.500000)                 0.000          0.000
        2      2      1     (-135.000000,97.500000)                 0.000          0.000
        3      3      1    (-135.000000,197.500000)                 0.000          0.000
        4      4      1    (-135.000000,297.500000)                 0.000          0.000
        5      5      1    (-135.000000,397.500000)                 0.000          0.000
        6      6      1    (-135.000000,497.500000)                 0.000          0.000
        7      7      1    (-135.000000,597.500000)                 0.000          0.000
        8      8      1    (-135.000000,697.500000)                 0.000          0.000
        9      9      1    (-135.000000,797.500000)                 0.000          0.000
       10     10      1    (-135.000000,897.500000)                 0.000          0.000
       11     11      1    (-135.000000,997.500000)                 0.000          0.000
       12     12      1   (-135.000000,1097.500000)                 0.000          0.000
       13     13      1   (-135.000000,1197.500000)                 0.000          0.000
       14     14      1   (-135.000000,1297.500000)                 0.000          0.000
       15     15      1   (-135.000000,1397.500000)                 0.000          0.000
       16     16      1   (-135.000000,1497.500000)                 0.000          0.000
       17     17      1   (-135.000000,1597.500000)                 0.000          0.000
       18     18      1   (-135.000000,1697.500000)                 0.000          0.000
       19     19      1   (-135.000000,1797.500000)                 0.000          0.000
       20     20      1   (-135.000000,1897.500000)                 0.000          0.000
       21     21      1   (-135.000000,1997.500000)                 0.000          0.000
       22     22      1   (-135.000000,2097.500000)                 0.000          0.000
       23     23      1   (-135.000000,2197.500000)                 0.000          0.000
       24     24      1   (-135.000000,2297.500000)                 0.000          0.000
       25     25      1   (-135.000000,2397.500000)                 0.000          0.000
       26     26      1   (-135.000000,2497.500000)                 0.000          0.000
       27     27      1   (-135.000000,2597.500000)                 0.000          0.000
       28     28      1   (-135.000000,2697.500000)                 0.000          0.000
       29     29      1   (-135.000000,2797.500000)                 0.000          0.000
       30     30      1   (-135.000000,2897.500000)                 0.000          0.000
       31     31      1   (-135.000000,2997.500000)                 0.000          0.000
       32     32      1   (-135.000000,3097.500000)                 0.000          0.000
       33     33      1   (-135.000000,3197.500000)                 0.000          0.000
       34     34      1   (-135.000000,3297.500000)               712.500          7.125
       35     35      1   (-135.000000,3397.500000)              1500.000         15.000
       36     36      1   (-135.000000,3497.500000)              1500.000         15.000
       37     37      1   (-135.000000,3597.500000)              1500.000         15.000
       38     38      1   (-135.000000,3697.500000)              1500.000         15.000
       39     39      1   (-135.000000,3797.500000)              1500.000         15.000
       40     40      1   (-135.000000,3897.500000)              1500.000         15.000
       41     41      1   (-135.000000,3997.500000)              1500.000         15.000
       42     42      1   (-135.000000,4097.500000)              1162.500         11.625
       43     43      1   (-135.000000,4197.500000)                 0.000          0.000
       44     44      1   (-135.000000,4297.500000)                 0.000          0.000
       45     45      1   (-135.000000,4397.500000)                 0.000          0.000
       46     46      1   (-135.000000,4497.500000)                 0.000          0.000
```



Relative area fill = transmittance value in PROLITH (15% = 0.15)

```
[Version]
13.2.2.1

[Parameters]
Tile Test Coarse
11047.5, 20115, -52.5
111, 203

[Data]
0       0.0475  0.2375  0.2375  0.2375  0.2375  0.2375  0.2375  0.2375  0.2375  0.2375  0.2375  0.2375  0.2375
0.2375  0.2375  0.235   0.3     0.3     0.3     0.3     0.3     0.3     0.3     0.3     0.3     0.3     0.3
0.3     0.3     0.3     0.3225  0.4125  0.4125  0.4125  0.4125  0.4125  0.4125  0.4125  0.4125  0.4125  0.4125
0.4125  0.4125  0.4125  0.4125  0.39188 0.27313 0.285   0.26125 0.26125 0.285   0.27313 0.26125 0.27313 0.285
0.26125 0.26125 0.285   0.27313 0.26125 0.27063 0.3     0.3     0.3     0.3     0.3     0.3     0.3     0.3
0.3     0.3     0.3     0.3     0.3     0.3     0.32813 0.42938 0.435   0.42375 0.42375 0.435   0.42938 0.42375
0.42938 0.435   0.42375 0.42375 0.435   0.42938 0.42375 0.36188 0       0       0       0       0       0       0
0       0       0       0       0       0       0       0       0       0       0       0       0       0.4375
0.50875 0.51625 0.50875 0.51625 0.50875 0.51625 0.50875 0.51625 0.50875 0.51625 0.50875 0.07875 0       0
0.30875 0.3875  0.3875  0.3875  0.3875  0.3875  0.3875  0.3875  0.3875  0.3875  0.3875  0.3875  0.07875 0
0.3275  0.4     0.4     0.4     0.4     0.4     0.2725  0       0       0.1275  0.4     0.4     0.4     0.4
0.4     0.0725  0       0       0.30875 0.3875  0.3875  0.3875  0.3875  0.3875  0.3875  0.3875  0.3875  0.3875
0.3875  0.3875  0.07875 0       0       0.4375  0.50875 0.51625 0.50875 0.51625 0.50875 0.51625 0.50875 0.51625
0.50875 0.51625 0.50875 0.07875 0       0       0.44625 0.525   0.525   0.525   0.525   0.525   0.525   0.525
0.525   0.525   0.525   0.525   0.07875 0
0       0.1     0.5     0.5     0.5     0.5     0.5     0.5     0.5     0.5     0.5     0.5     0.5     0.5
0.5     0.5     0.475   0.5     0.5     0.5     0.5     0.5     0.5     0.5     0.5     0.5     0.5     0.5
0.5     0.5     0.5     0.55    0.75    0.75    0.75    0.75    0.75    0.75    0.75    0.75    0.75    0.75
0.75    0.75    0.75    0.75    0.725   0.575   0.6     0.55    0.55    0.6     0.575   0.55    0.575   0.6
0.55    0.55    0.6     0.575   0.55    0.565   0.6     0.6     0.6     0.6     0.6     0.6     0.6     0.6
0.6     0.6     0.6     0.6     0.6     0.6     0.65    0.83    0.84    0.82    0.82    0.84    0.83    0.82
0.83    0.84    0.82    0.82    0.84    0.83    0.82    0.7     0       0       0       0       0       0       0
0       0       0       0       0       0       0       0       0       0       0       0       0       0.50875
0.36625 0.65875 0.36625 0.65875 0.36625 0.65875 0.36625 0.65875 0.36625 0.65875 0.36625 0.15    0       0
0.6     0.75    0.75    0.75    0.75    0.75    0.75    0.75    0.75    0.75    0.75    0.75    0.15    0
0.6125  0.75    0.75    0.75    0.75    0.75    0.5125  0       0       0.2375  0.75    0.75    0.75    0.75
0.75    0.1375  0       0       0.6     0.75    0.75    0.75    0.75    0.75    0.75    0.75    0.75    0.75
0.75    0.75    0.15    0       0       0.50875 0.36625 0.65875 0.36625 0.65875 0.36625 0.65875 0.36625 0.65875
0.36625 0.65875 0.36625 0.15    0       0       0.85    0.55375 0.475   0.92125 1       0.55375 0.475   0.92125 1
0.55375 0.475   0.92125 0.15    0
0       0.1     0.5     0.5     0.5     0.5     0.5     0.5     0.5     0.5     0.5     0.5     0.5     0.5
0.5     0.5     0.475   0.5     0.5     0.5     0.5     0.5     0.5     0.5     0.5     0.5     0.5     0.5
0.5     0.5     0.5     0.55    0.75    0.75    0.75    0.75    0.75    0.75    0.75    0.75    0.75    0.75
0.75    0.75    0.75    0.75    0.725   0.575   0.6     0.55    0.55    0.6     0.575   0.55    0.575   0.6
0.55    0.55    0.6     0.575   0.55    0.56125 0.575   0.575   0.575   0.575   0.575   0.575   0.575   0.575
0.575   0.575   0.575   0.575   0.575   0.575   0.62813 0.81938 0.83    0.80875 0.80875 0.83    0.81938 0.80875
0.81938 0.83    0.80875 0.80875 0.83    0.81938 0.80875 0.69063 0       0       0       0       0       0       0
0       0       0       0       0       0       0       0       0       0       0       0       0       0.84125
```

Aerial Image w/ and w/o PSF Flare for EUV EUV Example w/ flare (35 nm lines)

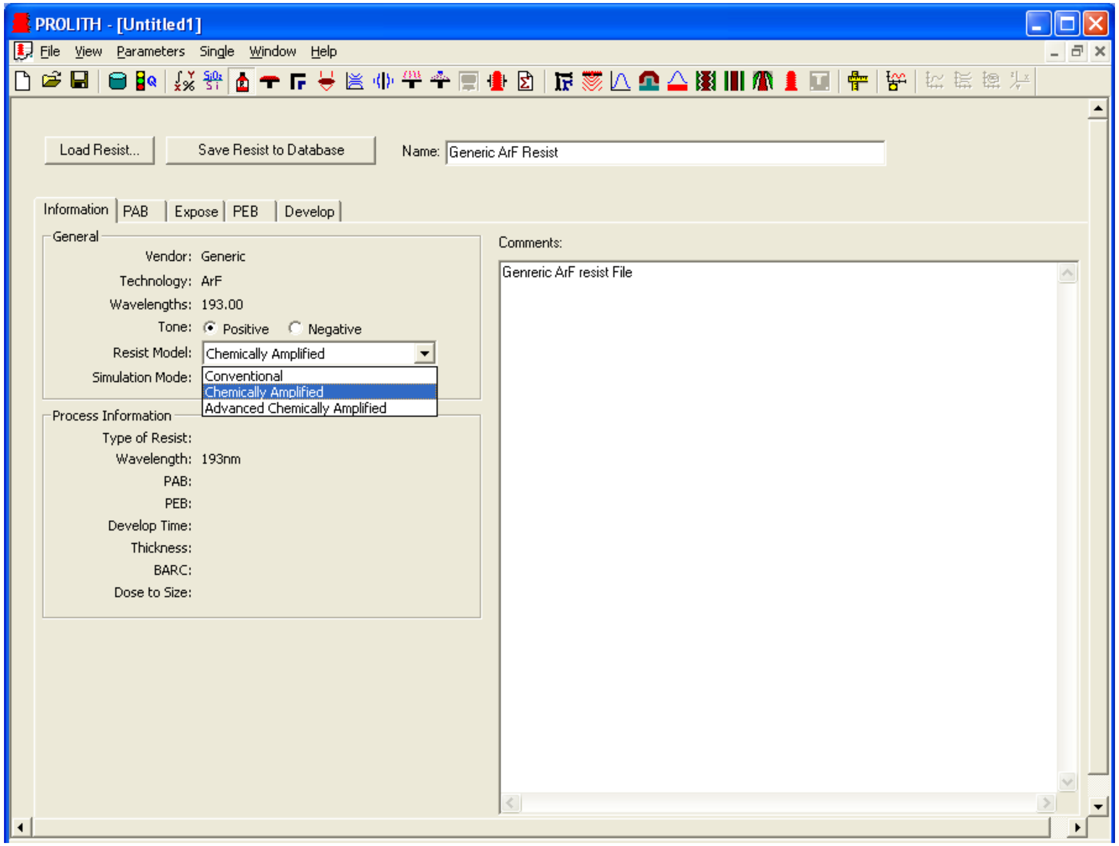


Less Contrast w/ Flare

Resist Model Updates

Chemically Amplified Resist Model

- Information Tab plus 4 parameter tabs
  - PAB (softbake)
  - Expose
  - PEB
  - Develop



Name: Generic ArF Resist

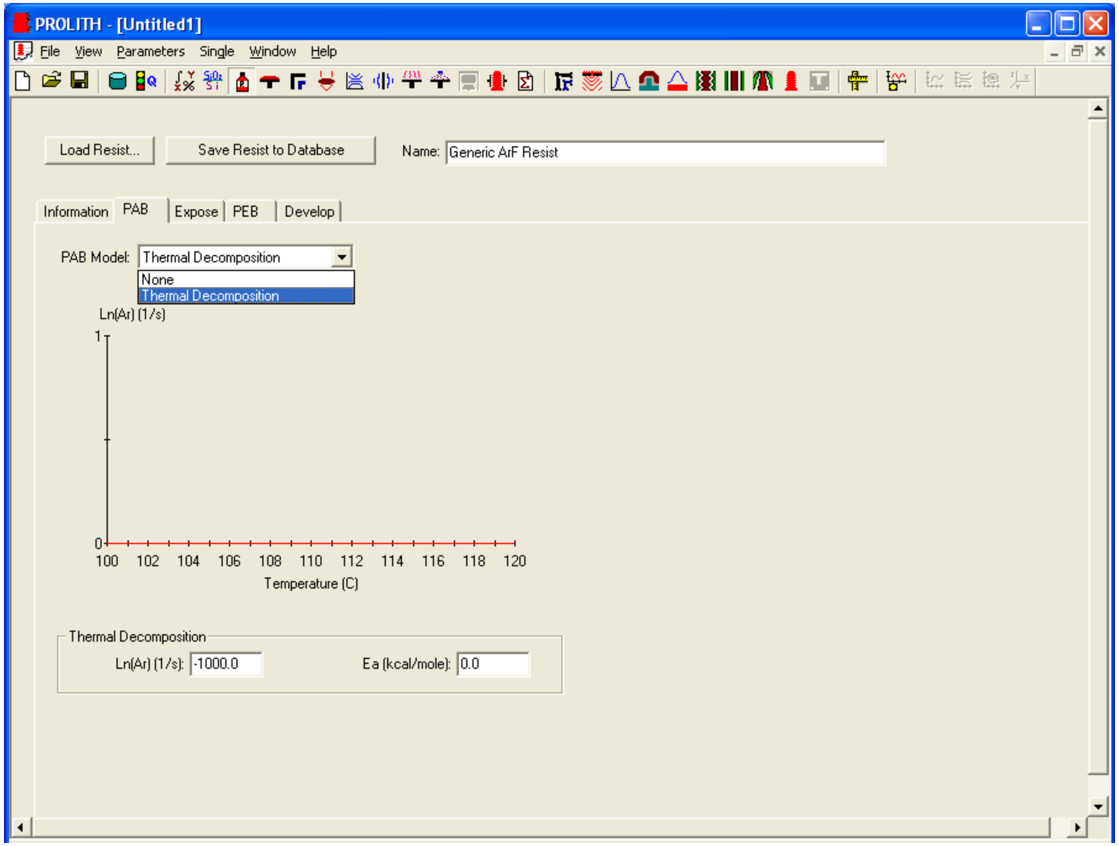
Vendor: Generic
Technology: ArF
Wavelengths: 193.00
Tone: ● Positive ○ Negative
Resist Model: Chemically Amplified
Simulation Mode:

Type of Resist:
Wavelength: 193nm
PAB:
PEB:
Develop Time:
Thickness:
BARC:
Dose to Size:

Comments:
Genreric ArF resist File

Chemically Amplified Resist – PAB Tab

- 2 Options
  - **None.** *Choose this option,* the thermal decomposition model describes the decomposition of PAC in conventional (Novolak) resist, not appropriate for Chemically Amplified systems.
  - **Thermal Decomposition**: this option is included to support legacy files only.



Name: Generic ArF Resist

PAB Model: Thermal Decomposition

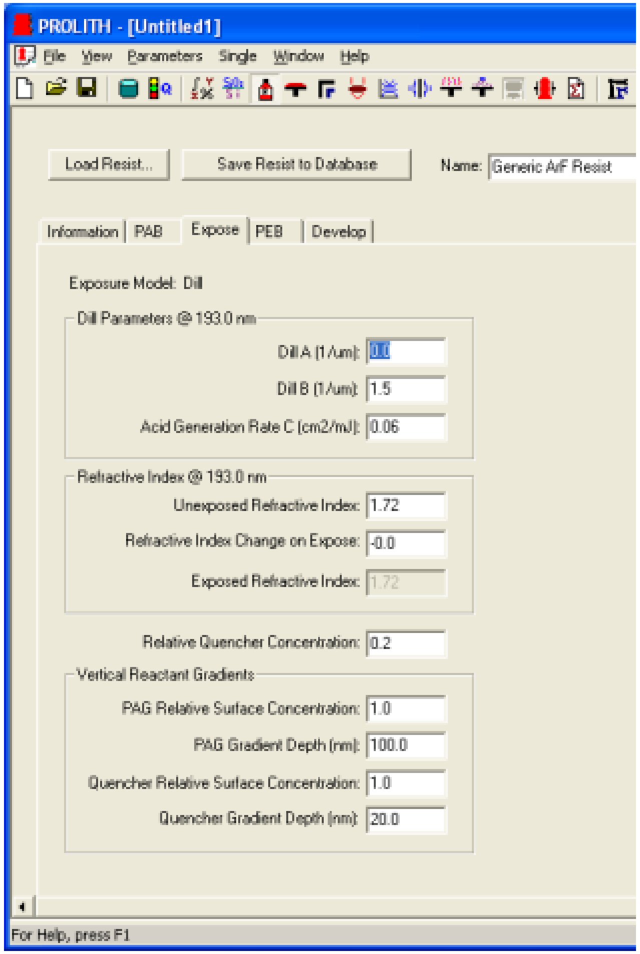
Thermal Decomposition

Ln(Ar) (1/s): -1000.0

Ea (kcal/mole): 0.0

Chemically Amplified Resist – Expose Tab

- Only one expose model (Dill)
- Specify Optical Parameters
  - Dill A, Dill B and Acid Generation rate C (Dill A should usually be 0)
- Specify unexposed index and delta upon exposure (this is retained for legacy reasons)
- Vertical Reactant Gradients
  - New user feature
  - Precise Profile Control
  - See following slide
- NOTE: Quencher loading is specified here.



Name: Generic ArF Resist

Exposure Model: Dill

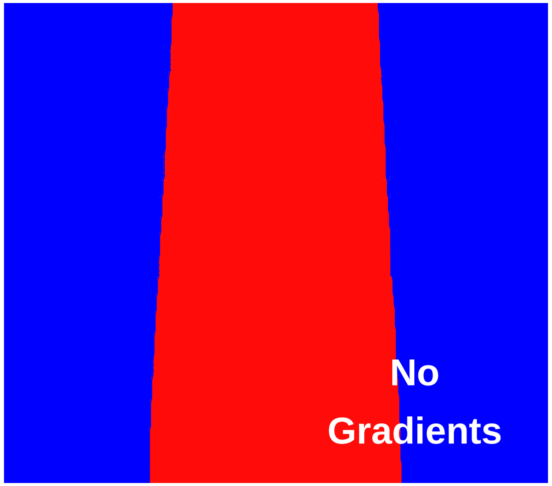
Dill Parameters @ 193.0 nm
Dill A (1/um): 0.0
Dill B (1/um): 1.5
Acid Generation Rate C (cm2/mJ): 0.06

Refractive Index @ 193.0 nm
Unexposed Refractive Index: 1.72
Refractive Index Change on Expose: -0.0
Exposed Refractive Index: 1.72

Relative Quencher Concentration: 0.2

Vertical Reactant Gradients
PAG Relative Surface Concentration: 1.0
PAG Gradient Depth (nm): 100.0
Quencher Relative Surface Concentration: 1.0
Quencher Gradient Depth (nm): 20.0

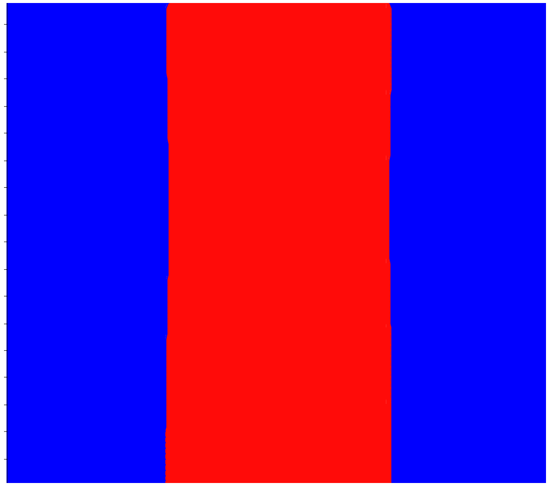
Chemically Amplified Resist – Expose Tab Gradient Effects – Profile Control

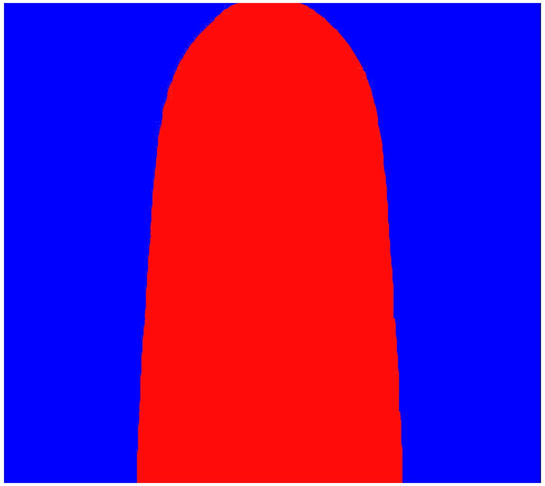


Quencher Gradient

Rel. surface conc. = 1.2

Gradient Depth = 45nm

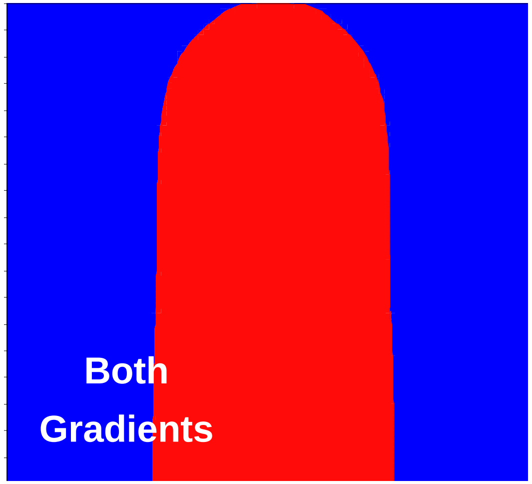




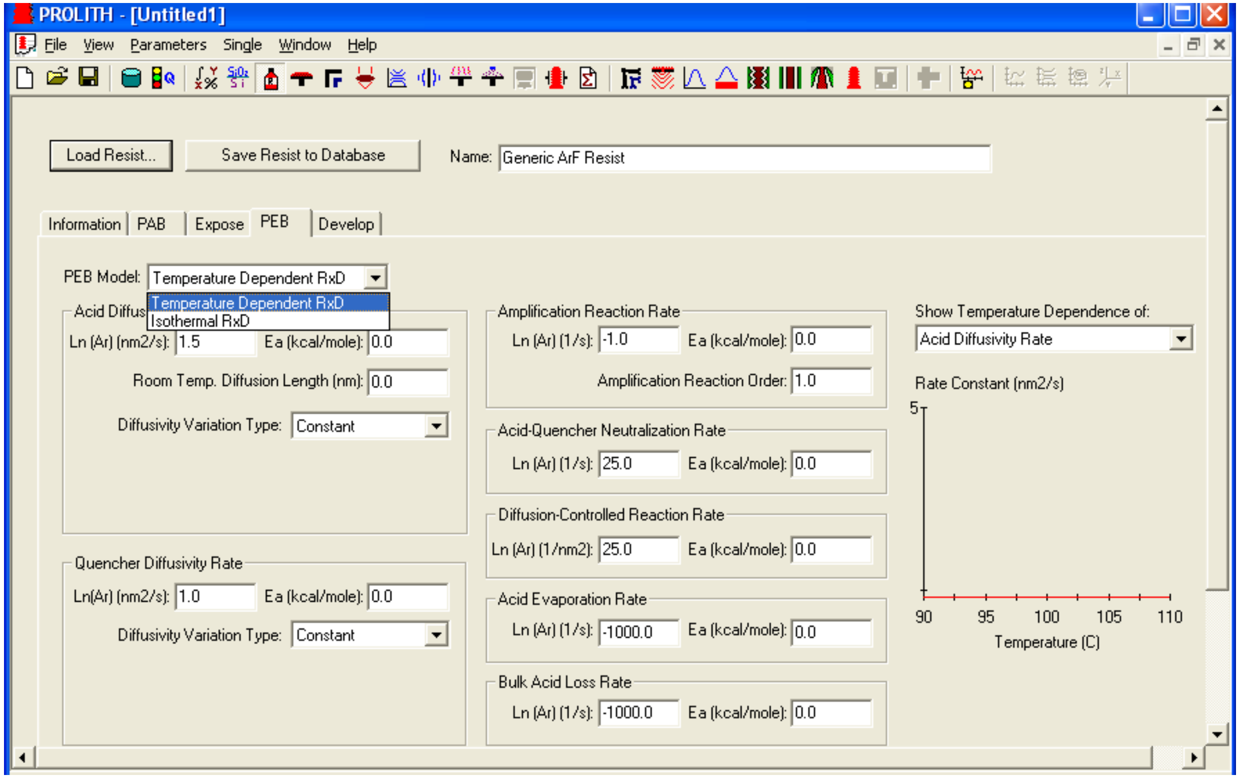
PAG Gradient

Rel. surface conc. = 4

Gradient Depth = 1.5nm



Chemically Amplified Resist – PEB Tab



Name: Generic ArF Resist

PEB Model: Temperature Dependent RxD

Acid Diffusivity Rate
Ln (Ar) (nm2/s): 1.5 Ea (kcal/mole): 0.0
Room Temp. Diffusion Length (nm): 0.0
Diffusivity Variation Type: Constant

Quencher Diffusivity Rate
Ln(Ar) (nm2/s): 1.0 Ea (kcal/mole): 0.0
Diffusivity Variation Type: Constant

Amplification Reaction Rate
Ln (Ar) (1/s): -1.0 Ea (kcal/mole): 0.0
Amplification Reaction Order: 1.0

Acid-Quencher Neutralization Rate
Ln (Ar) (1/s): 25.0 Ea (kcal/mole): 0.0

Diffusion-Controlled Reaction Rate
Ln (Ar) (1/nm2): 25.0 Ea (kcal/mole): 0.0

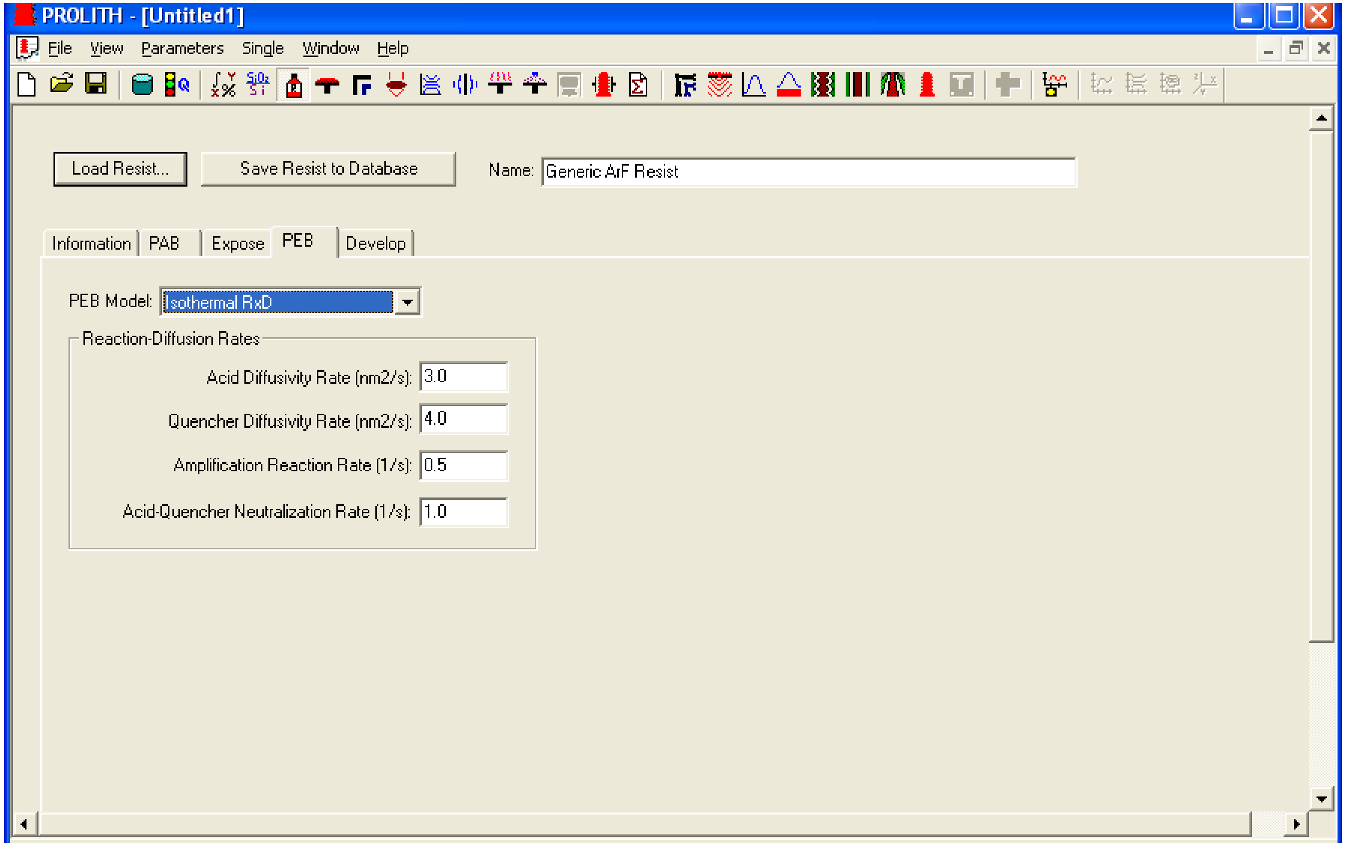
Acid Evaporation Rate
Ln (Ar) (1/s): -1000.0 Ea (kcal/mole): 0.0

Bulk Acid Loss Rate
Ln (Ar) (1/s): -1000.0 Ea (kcal/mole): 0.0

Show Temperature Dependence of: Acid Diffusivity Rate

- **Two PEB options available: Temperature dependant and Isothermal.**
- ***Temperature dependant:* is a rearranged version of previous model.**
- ***Isothermal*: Simplified model with essential parameters to ease user calibrations.**

Chemically Amplified Resist – PEB Tab
New Isothermal model



Name: Generic ArF Resist

PEB Model: Isothermal RxD

Reaction-Diffusion Rates

Acid Diffusivity Rate (nm2/s): 3.0

Quencher Diffusivity Rate (nm2/s): 4.0

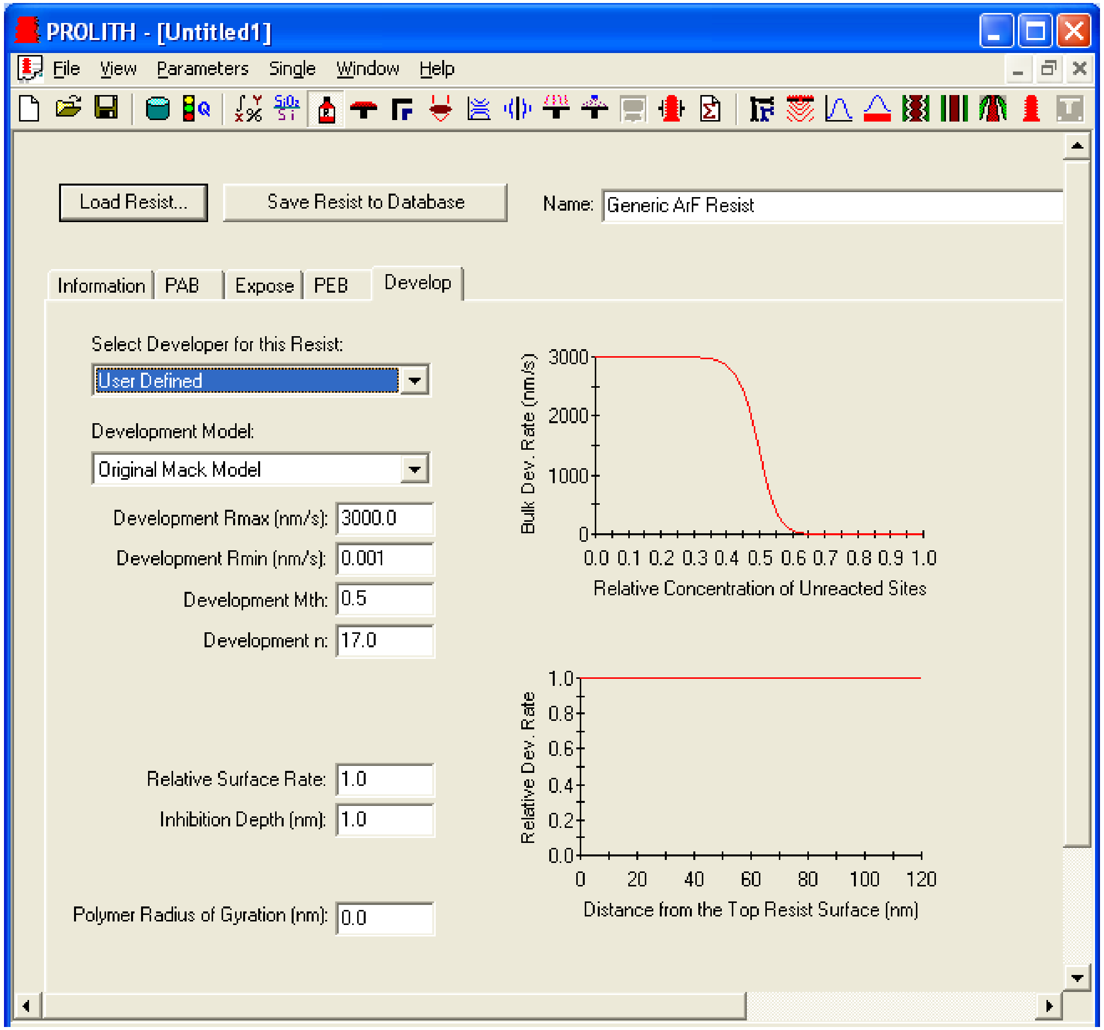
Amplification Reaction Rate (1/s): 0.5

Acid-Quencher Neutralization Rate (1/s): 1.0

- **Isothermal removes the Arrhenius behavior from each variable.**
- **Based on our extensive calibration experience, other model facets have been removed or hardwired to the values seen in 99.9% of calibration cases.**

Chemically Amplified Resist – Develop Tab

- **Develop Tab essentially unchanged**
- **Polymer radius of gyration parameter added to all models for stochastic simulations, but left available in continuum mode. (see Later)**



Name: Generic ArF Resist

Select Developer for this Resist: User Defined

Development Model: Original Mack Model

Development Rmax (nm/s): 3000.0

Development Rmin (nm/s): 0.001

Development Mth: 0.5

Development n: 17.0

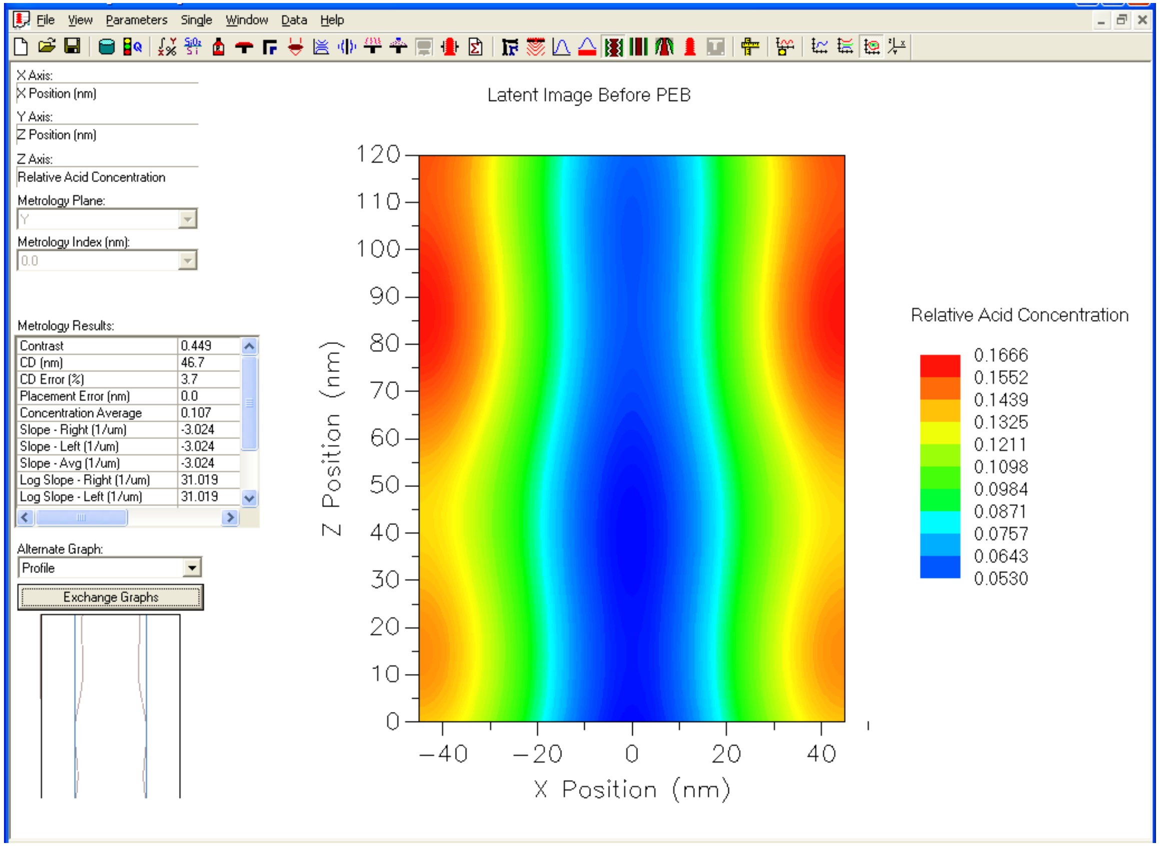
Relative Surface Rate: 1.0

Inhibition Depth (nm): 1.0

Polymer Radius of Gyration (nm): 0.0

Chemically Amplified Resist Model
Change to Exposed Latent Image Output Screen

- Exposed latent image output screen updated from relative PAC (sic) concentration to relative acid concentration
- This help consistency with stochastic output and visualization of gradients.



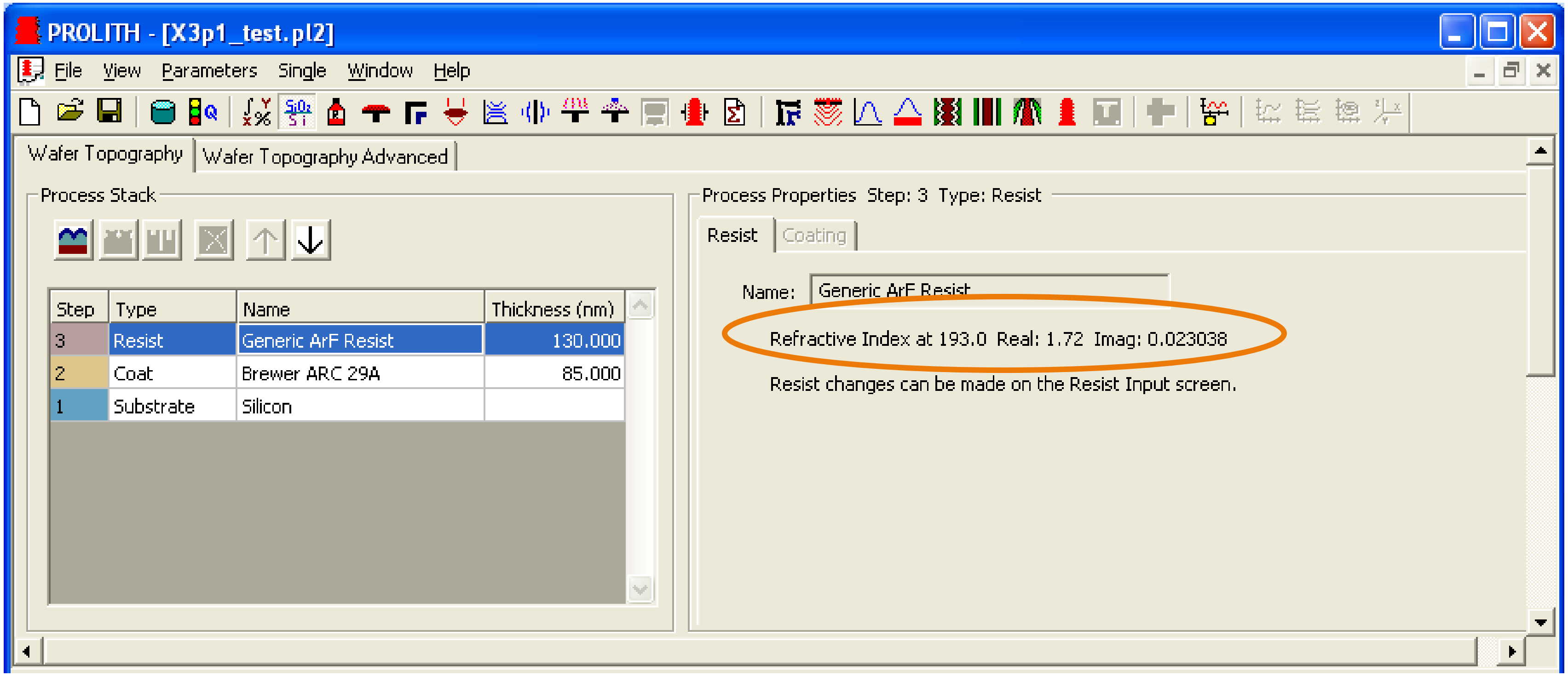
X Axis: X Position (nm)
Y Axis: Z Position (nm)
Z Axis: Relative Acid Concentration
Metrology Plane: Y
Metrology Index (nm): 0.0

Metrology Results:

Contrast	0.449
CD (nm)	46.7
CD Error (%)	3.7
Placement Error (nm)	0.0
Concentration Average	0.107
Slope - Right (1/um)	-3.024
Slope - Left (1/um)	-3.024
Slope - Avg (1/um)	-3.024
Log Slope - Right (1/um)	31.019
Log Slope - Left (1/um)	31.019

Alternate Graph: Profile

Changes to Wafer Processes Screen



Process Properties Step: 3 Type: Resist

Step	Type	Name	Thickness (nm)
3	Resist	Generic ArF Resist	130.000
2	Coat	Brewer ARC 29A	85.000
1	Substrate	Silicon	

Name: Generic ArF Resist

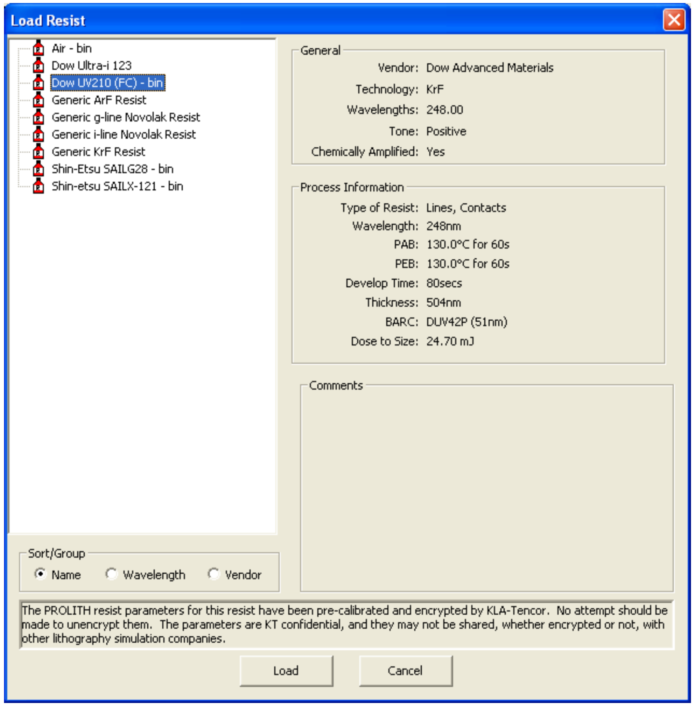
Refractive Index at 193.0 Real: 1.72 Imag: 0.023038

Resist changes can be made on the Resist Input screen.

- Resist refractive index given on film stack page for both encrypted and unencrypted resists.
- Imaginary index (k) is calculated from absorbance parameters.

Photo Resist Database

- The photo resist database has been overhauled for PROLITH X3 in collaboration with Dow Advanced Materials, JSR, Shin-Etsu and TOK.
- Resist (.res) files exist in two formats:
  - Machine readable [labelled with the ‘- bin’ extension]
  - Text files [no additional extension]
- The available resist fall into the following categories:
  - **Generic resists –** open parameter files with typical values, to use as start point for AutoTune calibrations.
  - **FINLE Certified (FC) –** State-of-the-art calibrated resist models (RMS Error < 2.5nm)
  - **Non-FC resists –** Various older KT calibrated files with higher RMS errors and vendor supplied models with good pedigree are also provided.



- Air - bin
- Dow Ultra-i 123
- Dow UV210 (FC) - bin
- Generic ArF Resist
- Generic g-line Novolak Resist
- Generic i-line Novolak Resist
- Generic KrF Resist
- Shin-Etsu SAILG28 - bin
- Shin-etsu SAILX-121 - bin

General

Vendor: Dow Advanced Materials
Technology: KrF
Wavelengths: 248.00
Tone: Positive
Chemically Amplified: Yes

Process Information

Type of Resist: Lines, Contacts
Wavelength: 248nm
PAB: 130.0°C for 60s
PEB: 130.0°C for 60s
Develop Time: 80secs
Thickness: 504nm
BARC: DUV42P (51nm)
Dose to Size: 24.70 mJ

Comments

Sort/Group

● Name ○ Wavelength ○ Vendor

The PROLITH resist parameters for this resist have been pre-calibrated and encrypted by KLA-Tencor. No attempt should be made to unencrypt them. The parameters are KT confidential, and they may not be shared, whether encrypted or not, with other lithography simulation companies.

Material Database Update

- The materials database has been updated with the help of AZ Microelectronics, Brewer Science, Dow Advanced Materials and JSR to add new materials and remove obsoleted products.

- Material parameters are available for
    - Up-to-Date Commercial Bottom Anti-Reflection Coatings for all key wavelengths.
    - Commercial Top Anti-Reflection Coatings
    - Commercial Immersion Topcoats

- Example spin coat surfaces have been added to the database for the new general wafer topography feature.

Stochastic Lithography Modeling

Activating Stochastic Modeling – Numerics Screen

- To enter stochastic simulation mode several conditions must be met:

1. Wafer topography must be off.
2. Single Exposure Pass Only
3. Wafer Grid must be in ‘Target Grid Size’ Mode.
4. Simulation region must be 3D (have an X, Y and Z extent. (Requires a 2D Mask)
5. NOTE: Model based OPC must be off.

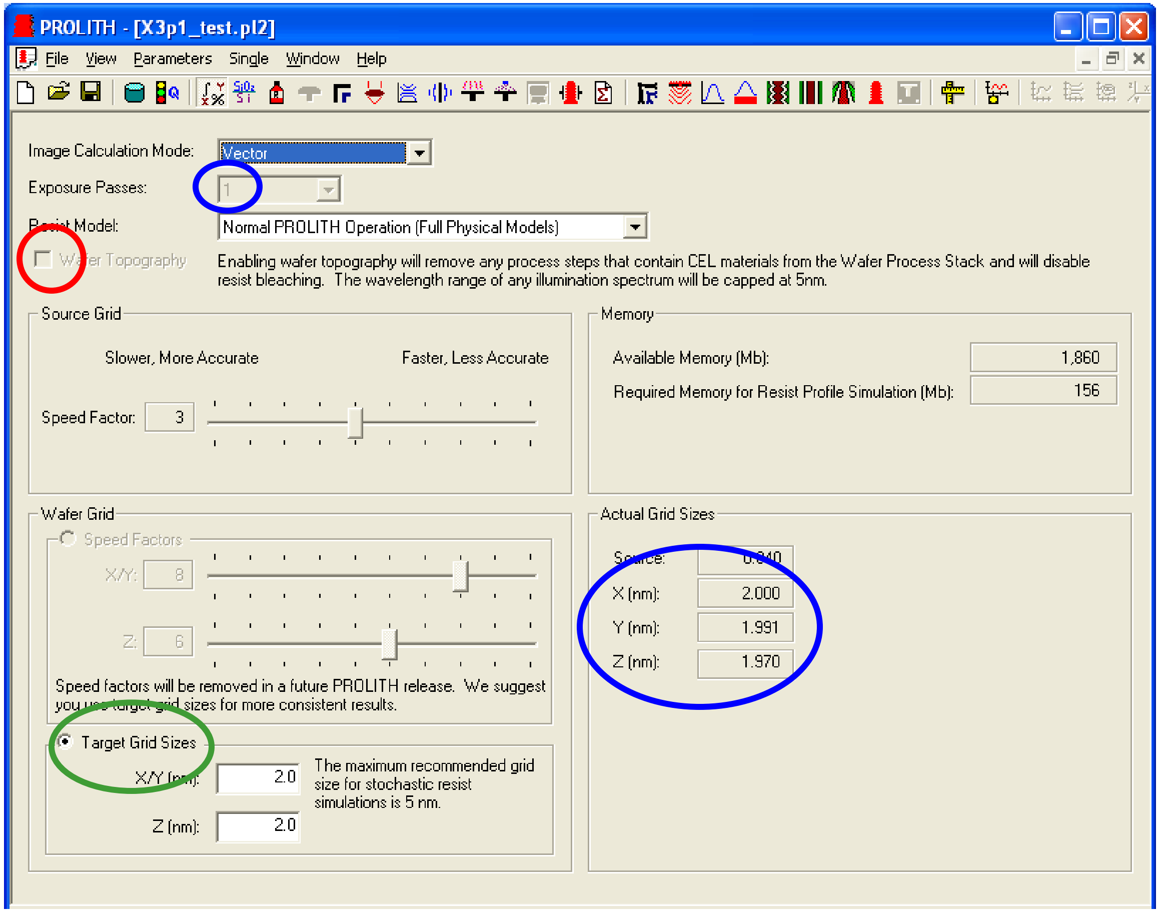


Image Calculation Mode: Vector

Exposure Passes: 1

Resist Model: Normal PROLITH Operation (Full Physical Models)

☐ Wafer Topography

Enabling wafer topography will remove any process steps that contain CEL materials from the Wafer Process Stack and will disable resist bleaching. The wavelength range of any illumination spectrum will be capped at 5nm.

Source Grid

Slower, More Accurate / Faster, Less Accurate

Speed Factor: 3

Memory

Available Memory (Mb): 1,860

Required Memory for Resist Profile Simulation (Mb): 156

Wafer Grid

○ Speed Factors

X/Y: 8

Z: 6

Speed factors will be removed in a future PROLITH release. We suggest you use target grid sizes for more consistent results.

● Target Grid Sizes

X/Y (nm): 2.0

Z (nm): 2.0

The maximum recommended grid size for stochastic resist simulations is 5 nm.

Actual Grid Sizes

Source: 0.040

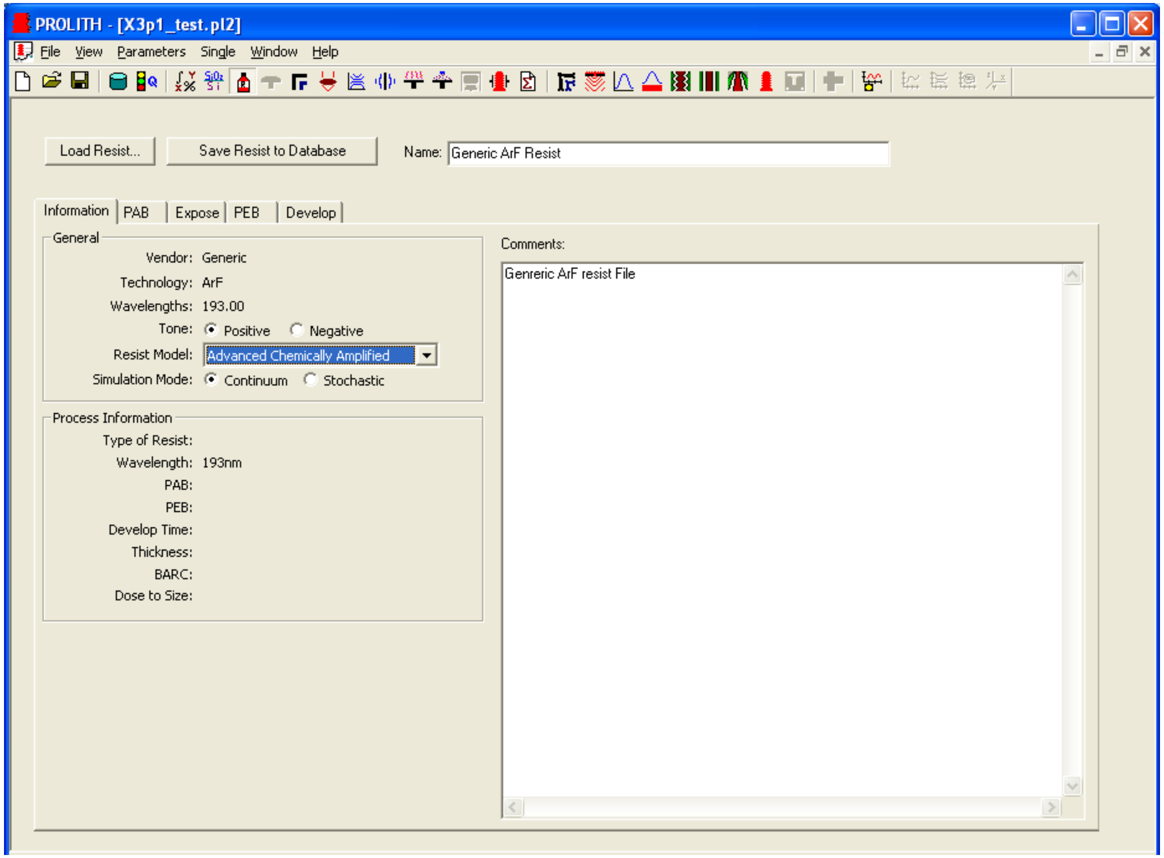
X (nm): 2.000

Y (nm): 1.991

Z (nm): 1.970

The Advanced Chemically Amplified Model

- The Advanced Chemically Amplified Resist Model can run in *stochastic* or *continuum* mode.
- Same basic tabs as the CA model, but
  - PAB model is always None
  - PEB model is always isothermal
  - Exposure model switches from Dill to Formulary



Name: Generic ArF Resist

General

Vendor: Generic

Technology: ArF

Wavelengths: 193.00

Tone: ● Positive ○ Negative

Resist Model: Advanced Chemically Amplified

Simulation Mode: ● Continuum ○ Stochastic

Process Information

Type of Resist:

Wavelength: 193nm

PAB:

PEB:

Develop Time:

Thickness:

BARC:

Dose to Size:

Comments:

Genreric ArF resist File

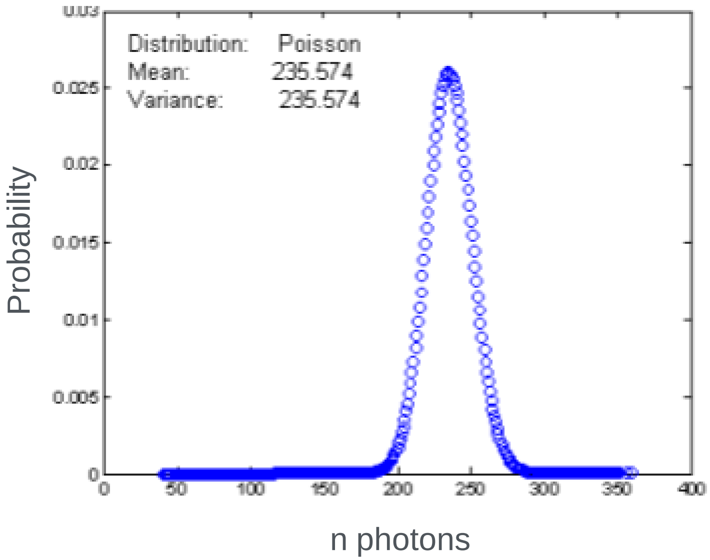
Modeling photon and molecule counting with the Poisson distribution

Poisson distribution: $probability(n;\lambda) = e^{-n}\dfrac{\lambda^n}{n!}$

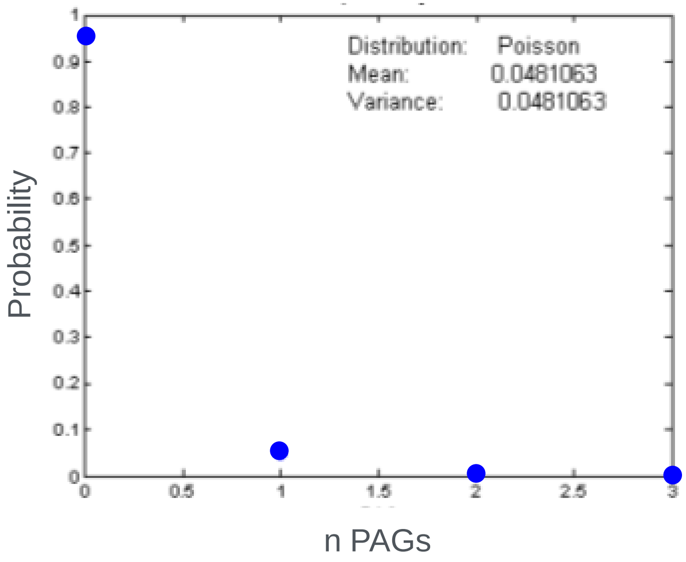
$\lambda = time \times \dfrac{n\ photons}{s} \quad n = n\ photons$

$\lambda = vol \times \dfrac{n\ molecules}{vol} \quad n = n\, molecules$

The probability of emitting *n* photons over a time interval



Probability of finding n PAGs in 1 nm^3 volume



Poisson's approximation to the binomial distribution is used to model the statistics of discrete photon and molecule counting

The average number of photons absorbed by a volume

Conservation of energy means that no absorption, no photochemistry

We are therefore interested in the number of photons absorbed by a volume of resist

The average number of photons absorbed by a volume or resist with absorbance *alpha:*

$$\langle n\ photons \rangle = \alpha \cdot I \cdot t \cdot V \cdot \frac{\lambda}{hc}$$

$\alpha = \text{absorption coefficient, } 1/m$

$I \cdot t = \text{exposure dose, } J/m^2$

$\lambda = \text{wavelength, } m$

$h = \text{Planck constant, } J \cdot s$

$c = \text{vacuum velocity of light, } m/s$

The probability of absorbing *n* photons in a volume of resist is a Poisson distribution with mean <*n photons*>

Acid generation by direct photolysis of PAG vs. ionization & electron scattering

PAG conversion by photolysis

Exposure mechanism at *ArF*

$$G \xrightarrow{h\nu \geq Eact} G^*$$

$$prob(G^* \rightarrow A) = \Phi$$

$$prob(G^* \rightarrow G) = 1 - \Phi$$

$$\phi \leq 1$$

PAG conversion by electron kinetic energy

Probable exposure mechanism at *EUV*

$$M \xrightarrow{h\nu \geq IP} M^+ + e_{KE=h\nu-IP}$$

$$G \xrightarrow{KE=h\nu-IP,\, KE\geq Eact} G^*$$

$$prob(G^* \rightarrow A) = \Phi$$

$$prob(G^* \rightarrow G) = 1 - \Phi$$

$$\phi \geq 0$$

$G = \text{PAG}$

$M = \text{Resist}$

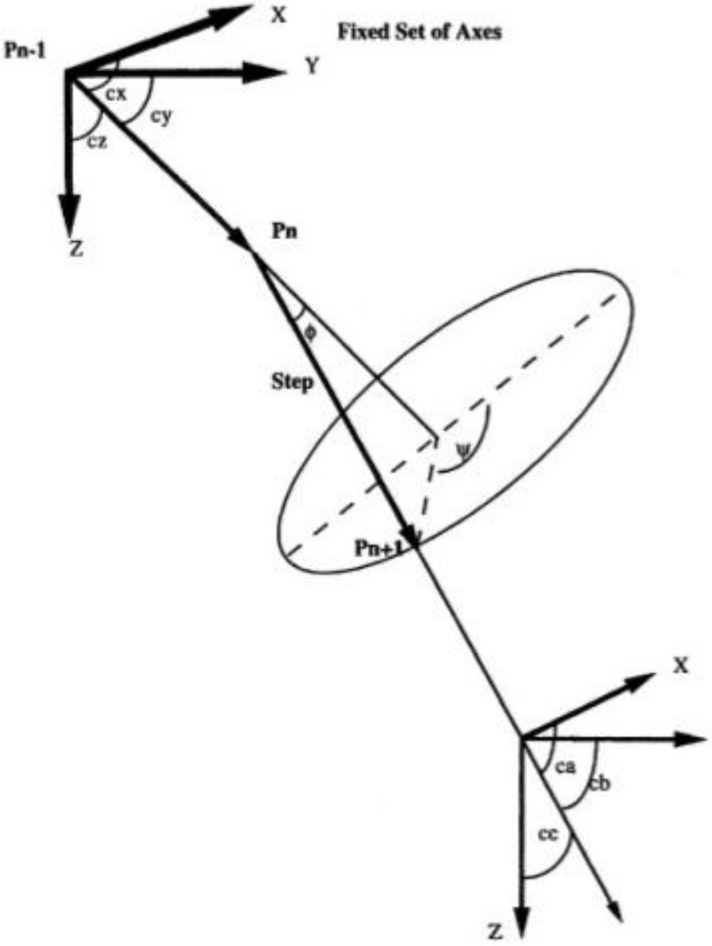
$A = \text{Acid}$

$\Phi = \text{Quantum efficiency}$

$$\phi = \frac{n\ Acids}{n\ absorbed\ photons} = \text{Quantum yield}$$

Acid yields at EUV are not explained by direct photolysis of PAG. Acid generation at EUV is hypothesized to be similar to that found in *e*-beam resists: via ionization and electron scattering

Simulation of electron scattering in resist



Discrete electron scattering in resist is modeled using the continuous slowing-down approximation coupled with a Monte Carlo method.

The resist will be considered as a medium with a lattice of atomic nuclei and a sea of light electrons, some tightly bound, some not. The MC method will model elastic collsions, inelastic collisions (and SE cascading) and the energy lost by each electron over a step. The method is valid to kinetic energy of about 20 *eV* (ca. 3-4 x the Fermi energy)

Several physical parameters controlling the interaction of electrons with the resist must be calculated as a function of energy:

$$\lambda_{el} = \text{elastic mean-free path}$$

$$\lambda_{inel} = \text{inelastic mean-free path}$$

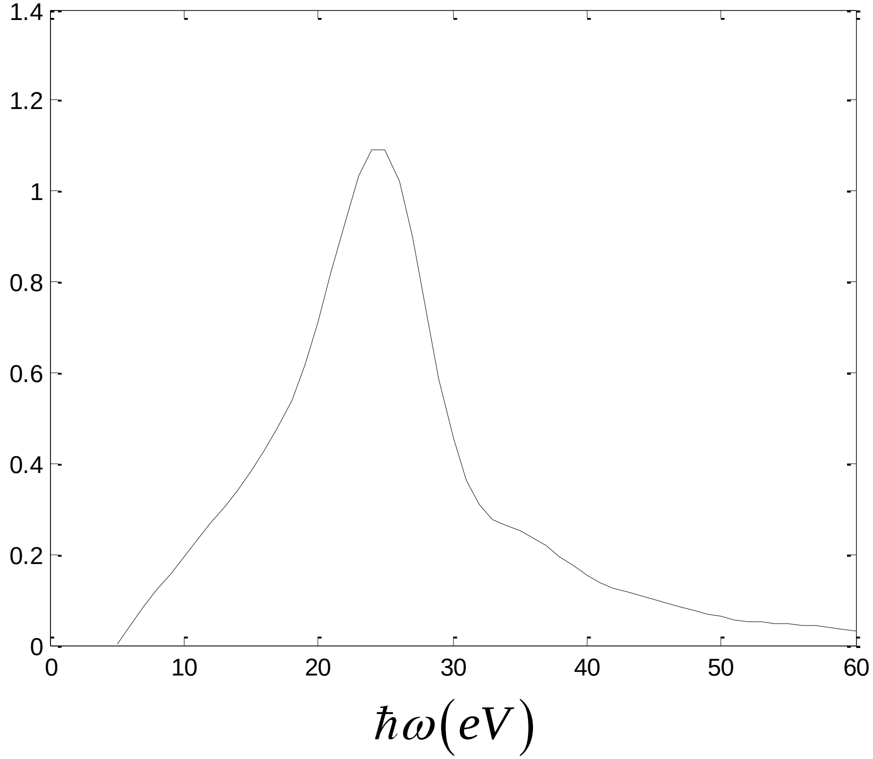
$$\frac{dE}{dS} = \text{stopping power}$$

$$\theta, \phi = \text{scattering angles}$$

Energy loss function

$$\mathrm{Im}\left[\frac{-1}{\varepsilon(0,\hbar\omega)}\right]=\frac{2n(\hbar\omega)k(\hbar\omega)}{\left(n(\hbar\omega)^2+k(\hbar\omega)^2\right)^2}$$

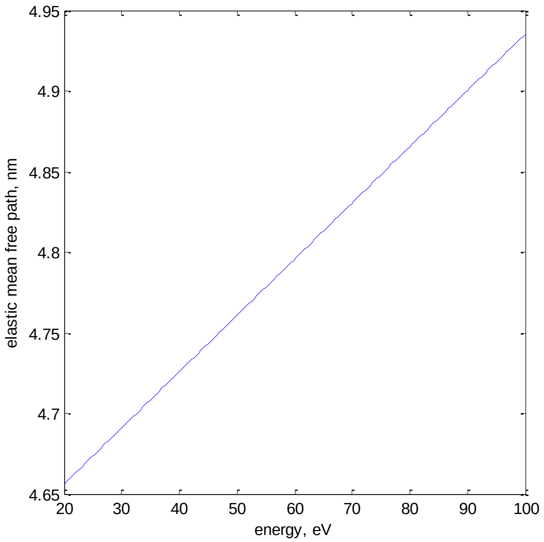
Energy loss function for polystyrene



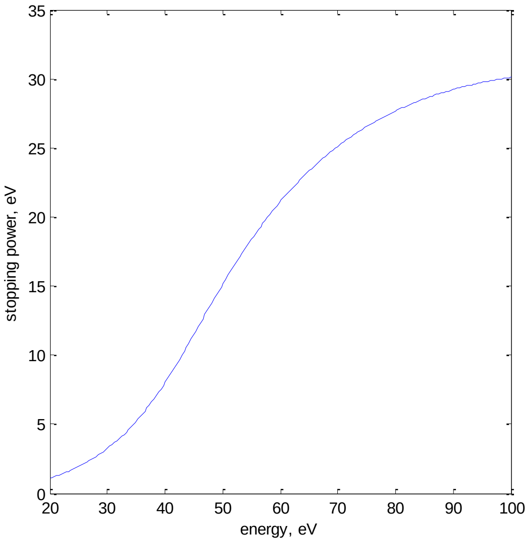
The energy loss function is the imaginary part of the dielectric spectrum
Can be computed from the resist dispersion curve over a range of energy
Energy loss function may be used to compute some low-energy electron scattering parameters

Elastic mean-free path, inelastic mean-free path and stopping power

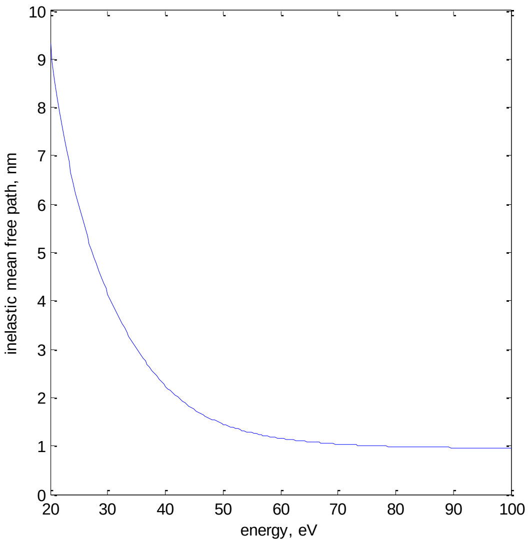
Example scattering parameters are computed based on the properties of polystyrene



Elastic mfp = f(E), *nm*



Stopping power = f(E), *eV / nm*



Inelastic mfp = f(E), *nm*

$$\lambda_{EL} = \frac{\alpha\left(2+\alpha\right)E^2\varepsilon_0^2}{N\pi Z^2 e^4}$$

$$-\frac{dE}{dS} = \frac{me^2}{\pi\hbar^2 E}\int_0^{E/2} \mathrm{Im}\left[\frac{-1}{\varepsilon\left(0,\hbar\omega\right)}\right] G_e\left(\frac{\hbar\omega}{E}\right)\hbar\omega\, d\hbar\omega$$

$$\frac{1}{\lambda_{INEL}} = \frac{me^2}{2\pi\hbar^2 E}\int_0^{E/2} \mathrm{Im}\left[\frac{-1}{\varepsilon\left(0,\hbar\omega\right)}\right] L_e\left(\frac{\hbar\omega}{E}\right)\hbar\omega\, d\hbar\omega$$

Stopping power = energy lost by an electron over a step, by energy loss function

Inelastic mean-free path = average distance between inelastic collisions, by energy loss function

Elastic mean-free path = average distance between elastic collisions, by first Born approximation

Discrete acid yield and electron scattering from one EUV ionization event

Simulation Parameters:

Resist Atomic Density = 100 atoms per *nm*^{3}

Average atomic number = (8*6 + 8*1)^(1/3)

PAG loading = 0.1 / *nm*^{3}

PAG reaction radius = 2.7 *nm*

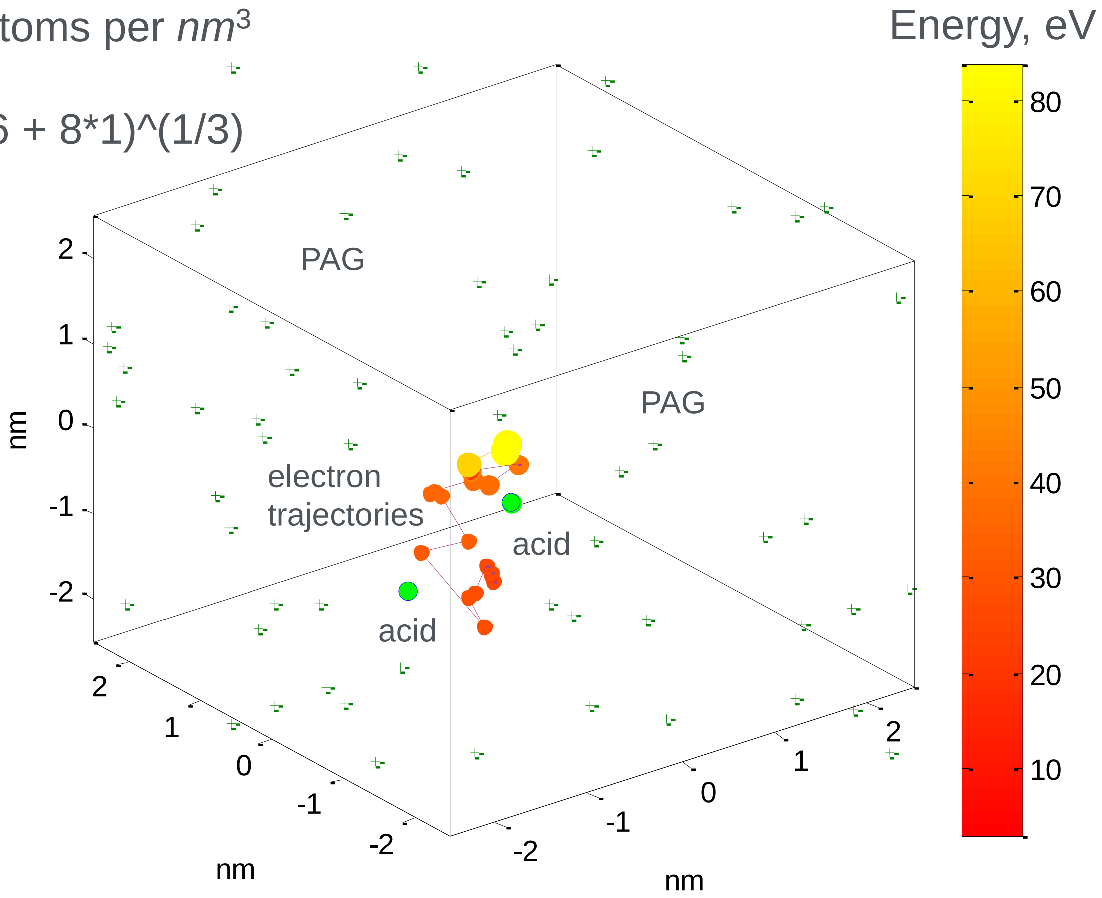
Ionization potential = 8 *eV*

PAG Excitation Energy = 2.0 *eV*

1 primary photoelectron

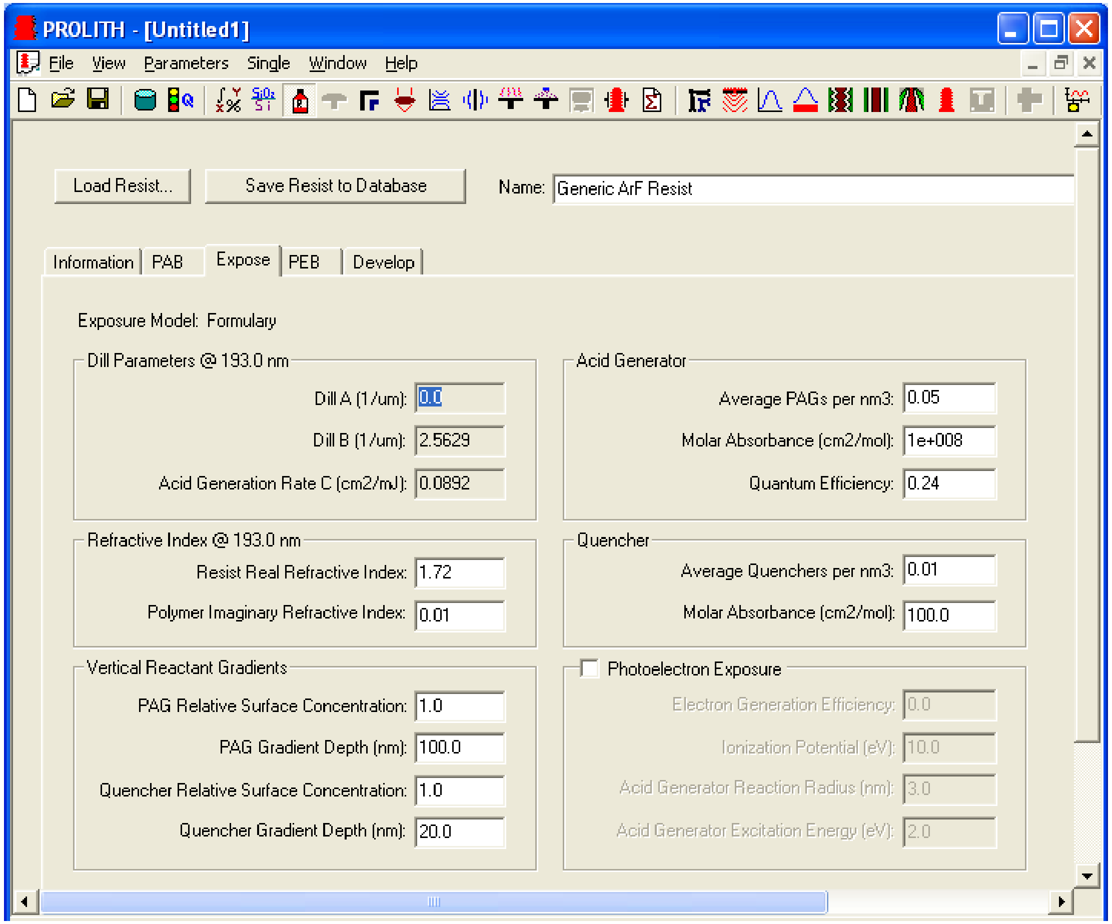
2 secondary electrons

Quantum yield = 2



The Advanced Chemically Amplified Model The Expose Tab

- The Expose Tab for the Advanced Chemically Amplified model switches to Formulary Mode
- Dill Values are calculated from other imputs
- Gradients behave identically to the Chemically amplified model
- Photoelectron Exposure is optional (EUV Only)



Name: Generic ArF Resist

Exposure Model: Formulary

Dill Parameters @ 193.0 nm

Dill A (1/um): 0.0

Dill B (1/um): 2.5629

Acid Generation Rate C (cm2/mJ): 0.0892

Acid Generator

Average PAGs per nm3: 0.05

Molar Absorbance (cm2/mol): 1e+008

Quantum Efficiency: 0.24

Refractive Index @ 193.0 nm

Resist Real Refractive Index: 1.72

Polymer Imaginary Refractive Index: 0.01

Quencher

Average Quenchers per nm3: 0.01

Molar Absorbance (cm2/mol): 100.0

Vertical Reactant Gradients

PAG Relative Surface Concentration: 1.0

PAG Gradient Depth (nm): 100.0

Quencher Relative Surface Concentration: 1.0

Quencher Gradient Depth (nm): 20.0

☐ Photoelectron Exposure

Electron Generation Efficiency: 0.0

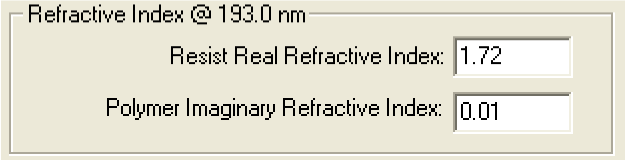
Ionization Potential (eV): 10.0

Acid Generator Reaction Radius (nm): 3.0

Acid Generator Excitation Energy (eV): 2.0

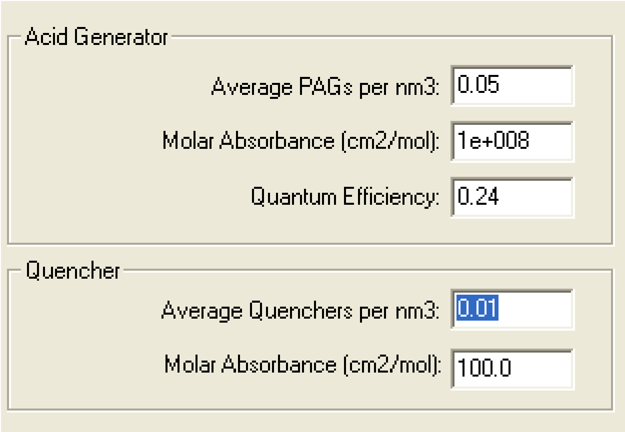
The Advanced Chemically Amplified Model
The Expose Tab – New Parameters

- Real index (n) for the RESIST film
- Imaginary index (k) for the resist POLYMER
- Average number of PAG/Quencher molecules per nm^3 in the DRY RESIST FILM.
- The Molar Absorbance of the PAG/Quencher. The molar absorbance is defined as –log10(I_trans / I_inc) / (path length * concentration) where I_trans is the intensity of the transmitted light and I_inc is the intensity of the incident light.
- Quantum Efficiency of the Acid Generator: Specifies the probability that an electronically excited photoacid generator (PAG) will convert to acid. Acid generators may be electronically excited by direct photon absorption or by a transference of kinetic energy.



Resist Real Refractive Index: 1.72

Polymer Imaginary Refractive Index: 0.01



Average PAGs per nm3: 0.05

Molar Absorbance (cm2/mol): 1e+008

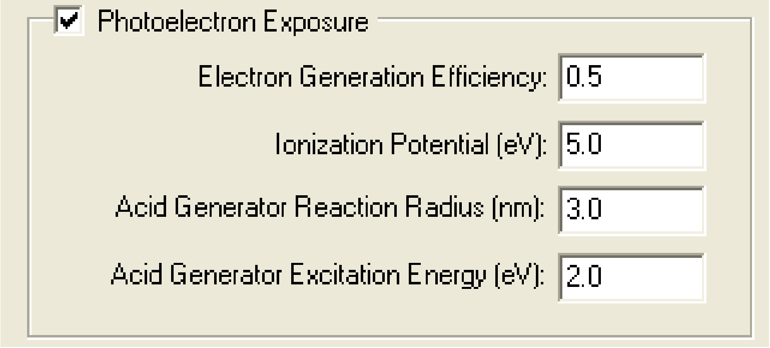
Quantum Efficiency: 0.24

Average Quenchers per nm3: 0.01

Molar Absorbance (cm2/mol): 100.0

The Advanced Chemically Amplified Model
The Expose Tab – Photoelectron Expose

- **Electron Generation Efficiency**: Specifies the probability that the resist will be ionized upon absorption of a high-energy photon
- **Ionization Potential (eV):** Specifies the minimum energy required to eject an electron from a molecule in the resist. The maximum kinetic energy of the ejected photoelectron will be KE = hv – IP.
- **Acid Generator Reaction Radius (nm):** Specifies the square root of the photoacid generator (PAG) reaction cross section, that is, how close an ejected electron must pass to the PAG center of mass to electronically excite the PAG.
- **Acid Generation Excitation Energy (eV):** Specifies the minimum kinetic energy required to electronically excite a photoacid generator (PAG).



☑ Photoelectron Exposure

Electron Generation Efficiency: 0.5

Ionization Potential (eV): 5.0

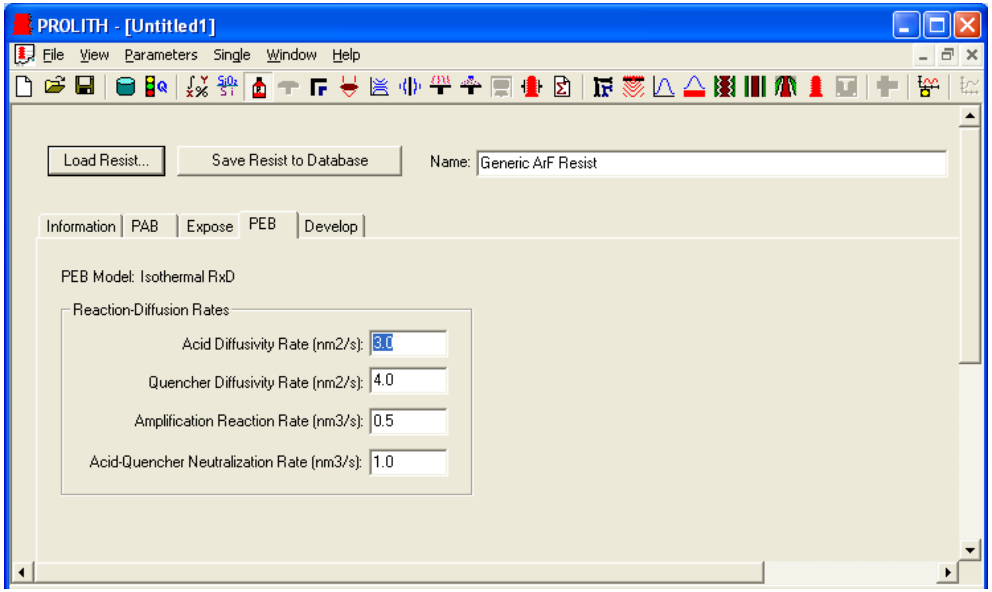
Acid Generator Reaction Radius (nm): 3.0

Acid Generator Excitation Energy (eV): 2.0

NOTE: Photoelectron exposure is only available in stochastic simulation mode.

The Advanced Chemically Amplified Model
The PEB Tab

- The isothermal model is essentially the same as that for the standard chemically amplified resists, except that the units for the Amplifications Reaction Rate and the Neutralization Rate change to reflect the absolute nature of the PAG and Quencher loadings



Name: Generic ArF Resist

PEB Model: Isothermal RxD

Reaction-Diffusion Rates

Acid Diffusivity Rate (nm2/s): 3.0

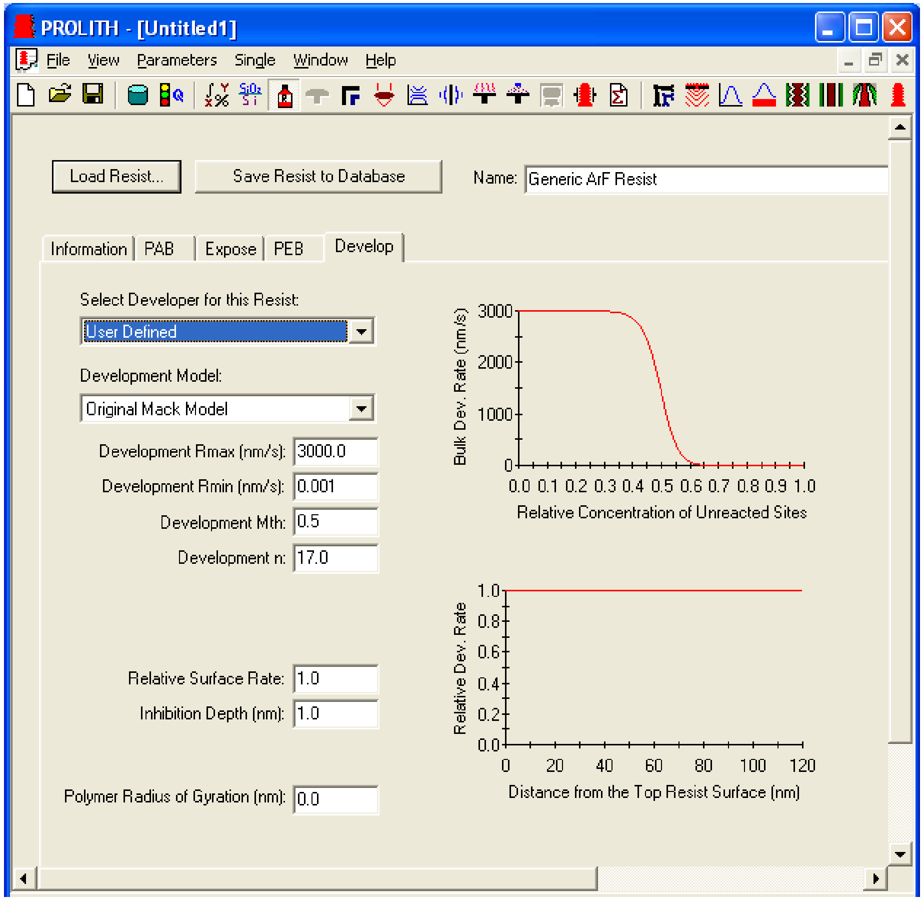
Quencher Diffusivity Rate (nm2/s): 4.0

Amplification Reaction Rate (nm3/s): 0.5

Acid-Quencher Neutralization Rate (nm3/s): 1.0

The Advanced Chemically Amplified Model
The Develop Tab

- From consideration of Critical Ionization theory a new parameters is added to development' Polymer Radius of gyration.
- The value is used to determine the average blocking level of each polymer molecule and decouple the simulation from the granularity formed by the chosen simulation region grid size.



Name: Generic ArF Resist

Select Developer for this Resist: User Defined

Development Model: Original Mack Model

Development Rmax (nm/s): 3000.0

Development Rmin (nm/s): 0.001

Development Mth: 0.5

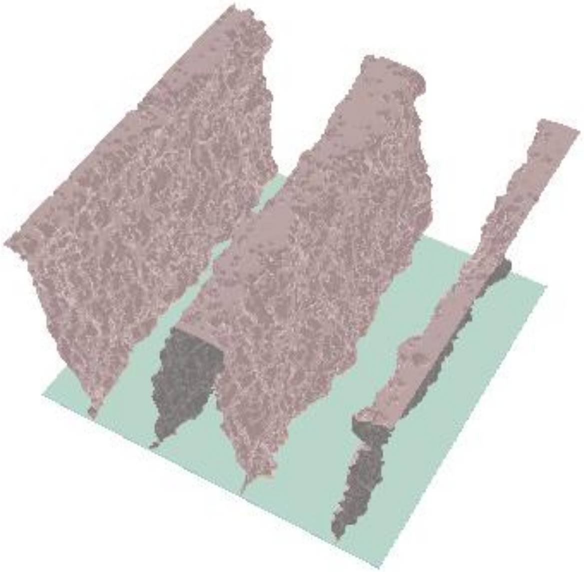
Development n: 17.0

Relative Surface Rate: 1.0

Inhibition Depth (nm): 1.0

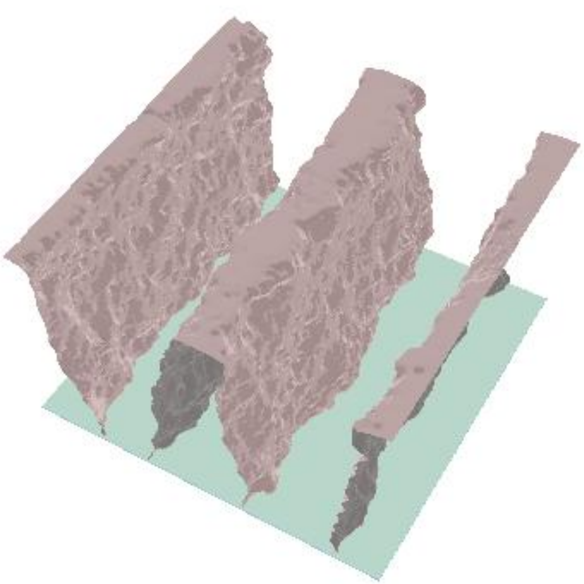
Polymer Radius of Gyration (nm): 0.0

The Advanced Chemically Amplified Model
The Develop Tab – Impact of Radius of Gyration



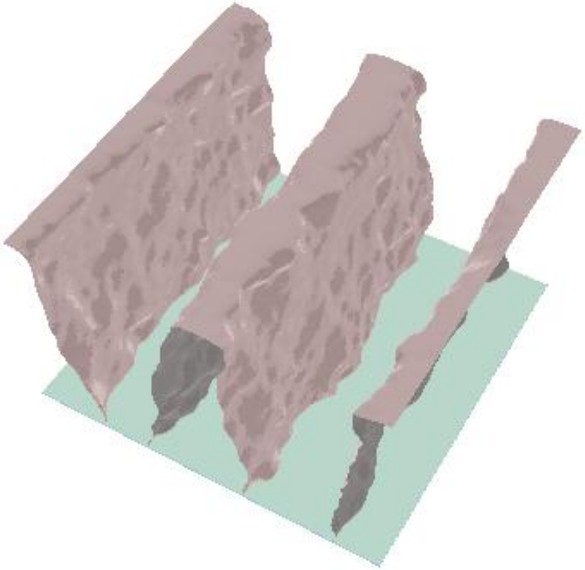
0 nm

Radius of Gyration



1 nm

Radius of Gyration

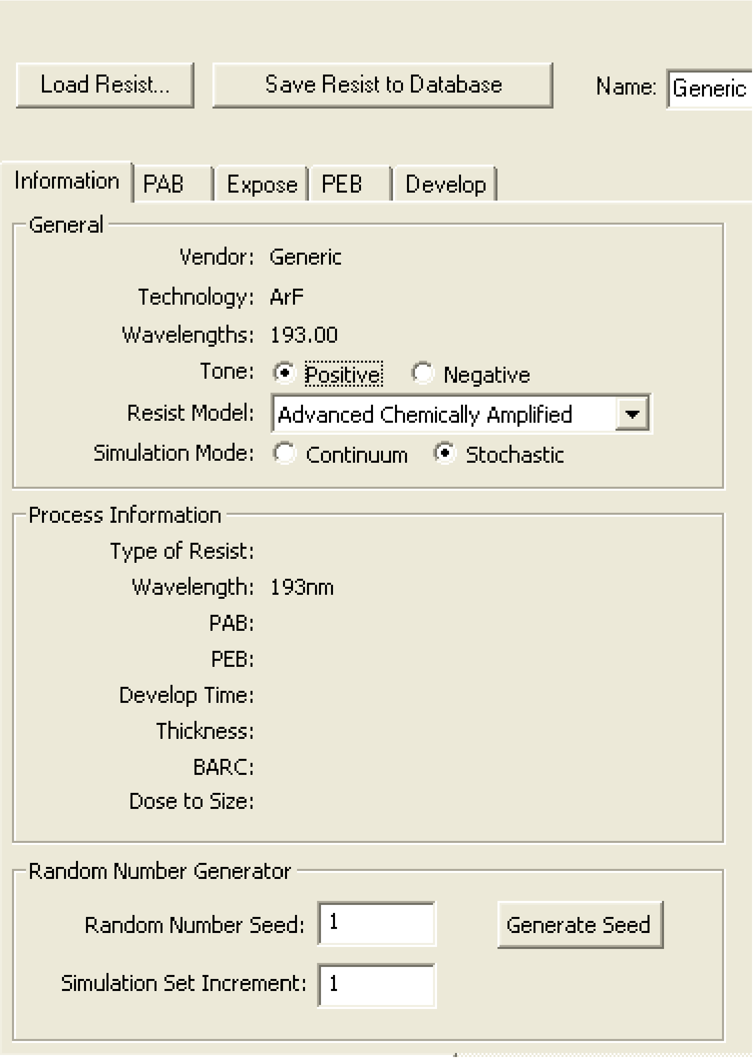


2 nm

Radius of Gyration

The Advanced Chemically Amplified Resist Model –Information Tab – The Stochastic Mode

- When an advanced chemically amplified resist is selected the user can toggle between *continuum* and *stochastic* simulation modes.
- In continuum mode, a regular *'mean-field'* simulation is performed using the parameters defined in the model (NOTE: at this time photoelectron exposure has no continuum implementation)
- When *stochastic* mode is chosen a probabilistic (Monte Carlo) simulation is performed.



Name: Generic

General

Vendor: Generic

Technology: ArF

Wavelengths: 193.00

Tone: ● Positive ○ Negative

Resist Model: Advanced Chemically Amplified

Simulation Mode: ○ Continuum ● Stochastic

Process Information

Type of Resist:

Wavelength: 193nm

PAB:

PEB:

Develop Time:

Thickness:

BARC:

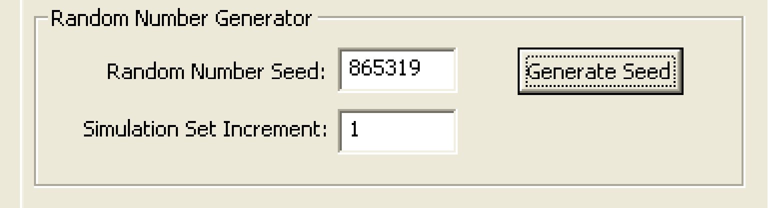
Dose to Size:

Random Number Generator

Random Number Seed: 1

Simulation Set Increment: 1

The Advanced Chemically Amplified Resist Model – Information Tab – The Stochastic Mode



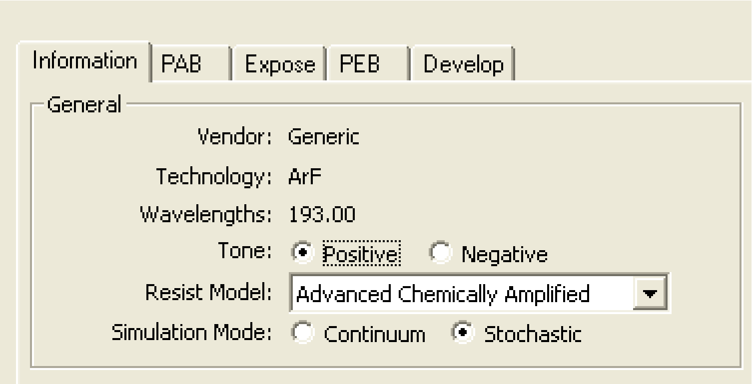
Random Number Seed: 865319

Simulation Set Increment: 1

- During a stochastic simulation random numbers are used to determine the outcome of many events based on their probability of occurring. e.g. Once a PAG is excited by a photon is an acid generated? (the probability in this case is the quantum efficiency).
- PROLITH uses a stream of random numbers keyed of a *seed* value. Every time the same simulation is run using the same seed value the same answer is obtained. This allows PROLITH to be validated from version to version.
- Since the user, will typically not want the results of a simulation set experiment to be highly correlated, a '*seed value increment*' can be specified. PROLITH will increase the seed number by this value for each unique point in the simulation set. (The use of Zero will mean that the same seed is used for all points in the simulation set).

The Advanced Chemically Amplified Resist Model - Switching Between Continuum and Stochastic Mode

- In photonic exposure mode (i.e. not with photoelectron exposure active). The user can toggle between continuum and stochastic mode getting consistent results.
- There is a metrology sensitivity to how well the mapping operates.
- Best agreement is seen when the **'raw'** measurement option is chosen



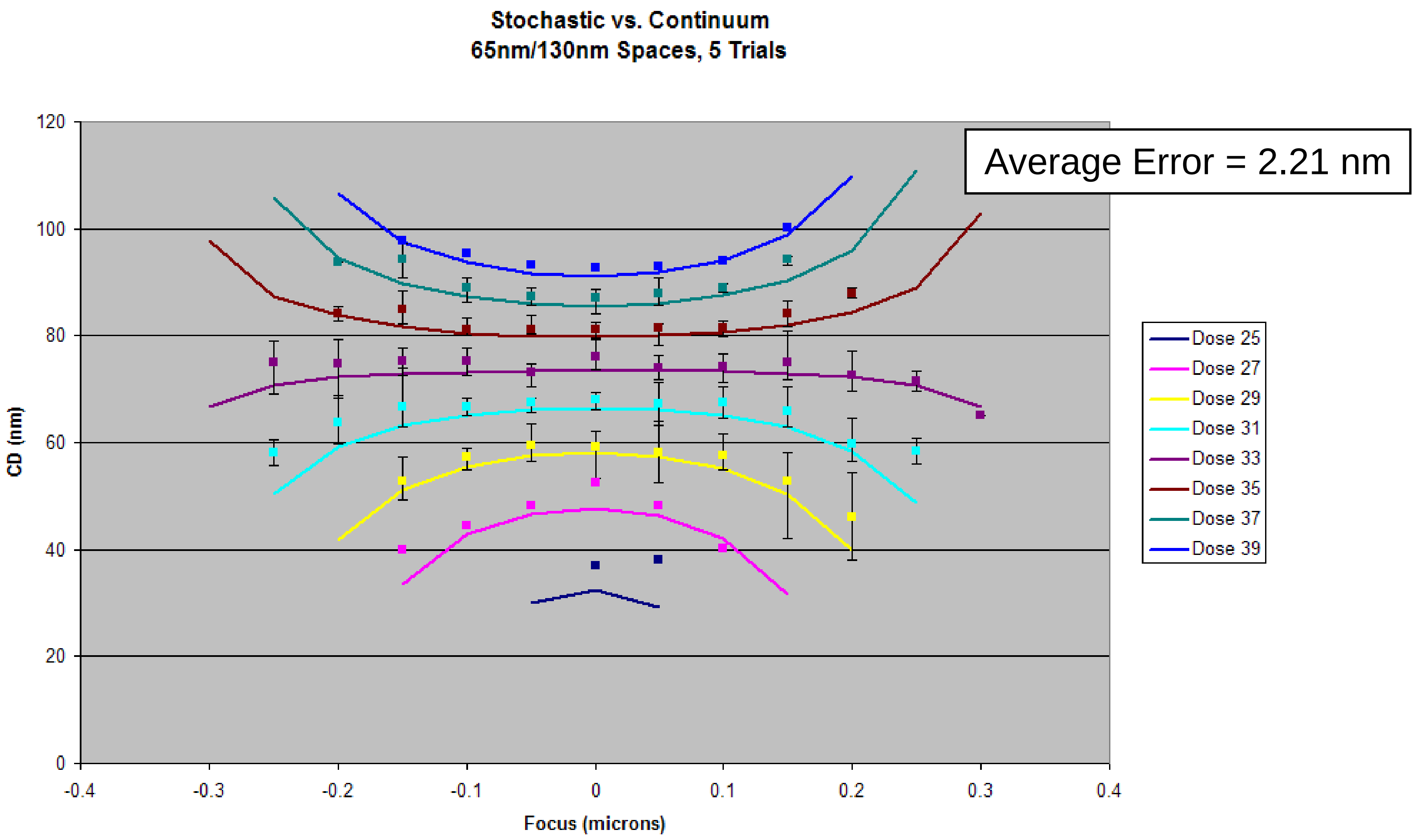
General

Vendor: Generic
Technology: ArF
Wavelengths: 193.00
Tone: ● Positive ○ Negative
Resist Model: Advanced Chemically Amplified
Simulation Mode: ○ Continuum ● Stochastic

Average Error Between CD results stochastic and continuum

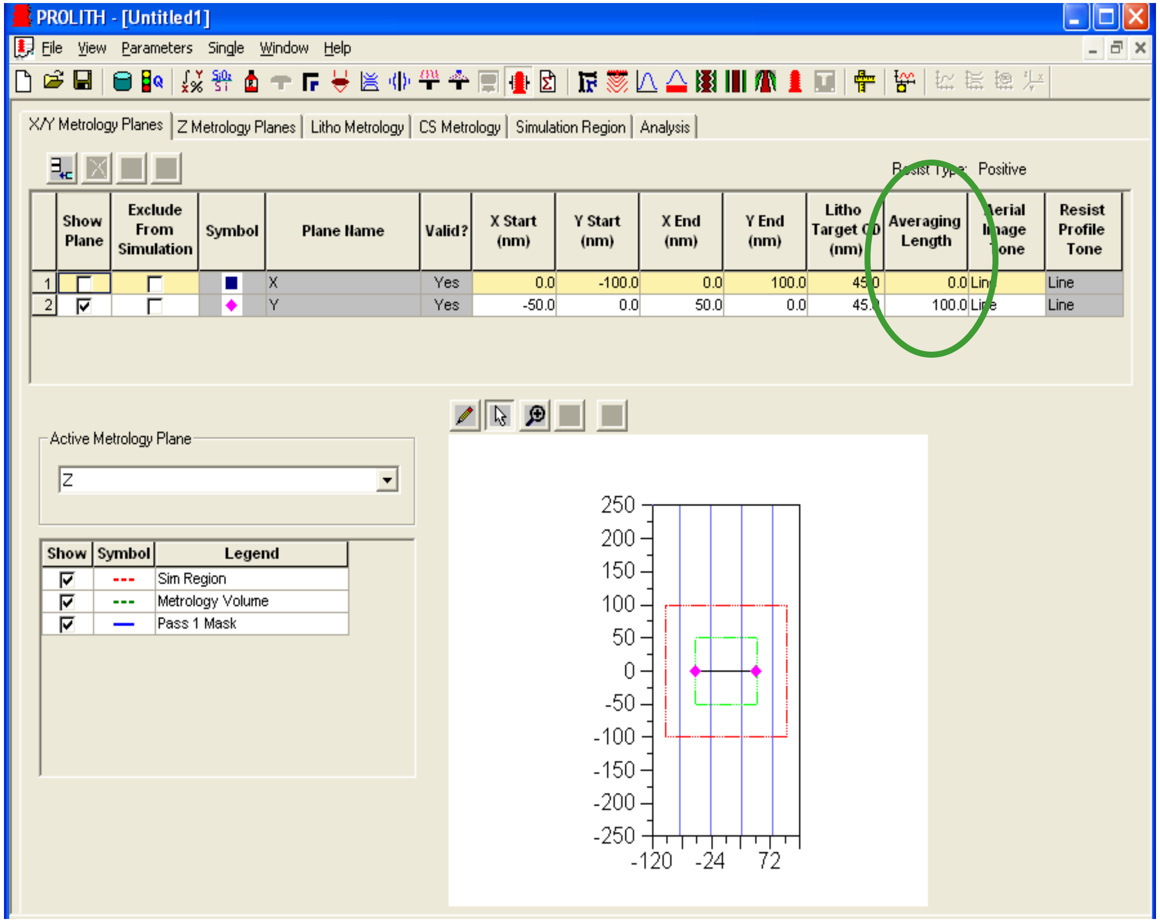
Threshold	Raw	Weighted
10%	2.21 nm	-1.73 nm
50%	1.84 nm	2.20 nm
90%	1.83 nm	6.50 nm

The Advanced Chemically Amplified Resist Model - Switching Between Continuum and Stochastic Mode



Changes to Metrology Planes – XY Planes
The Averaging Length

- ***Averaging Length***: Specifies in nanometers a length orthogonal to and centered on the metrology plane.
- For resist profile metrology, PROLITH performs measurements along the averaging length at sampling points consistent with the wafer grid and returns the **averaged** value.
- For default planes, the length is restricted to on grid values.
- For user defined planes any length can be entered.



Resist Type: Positive

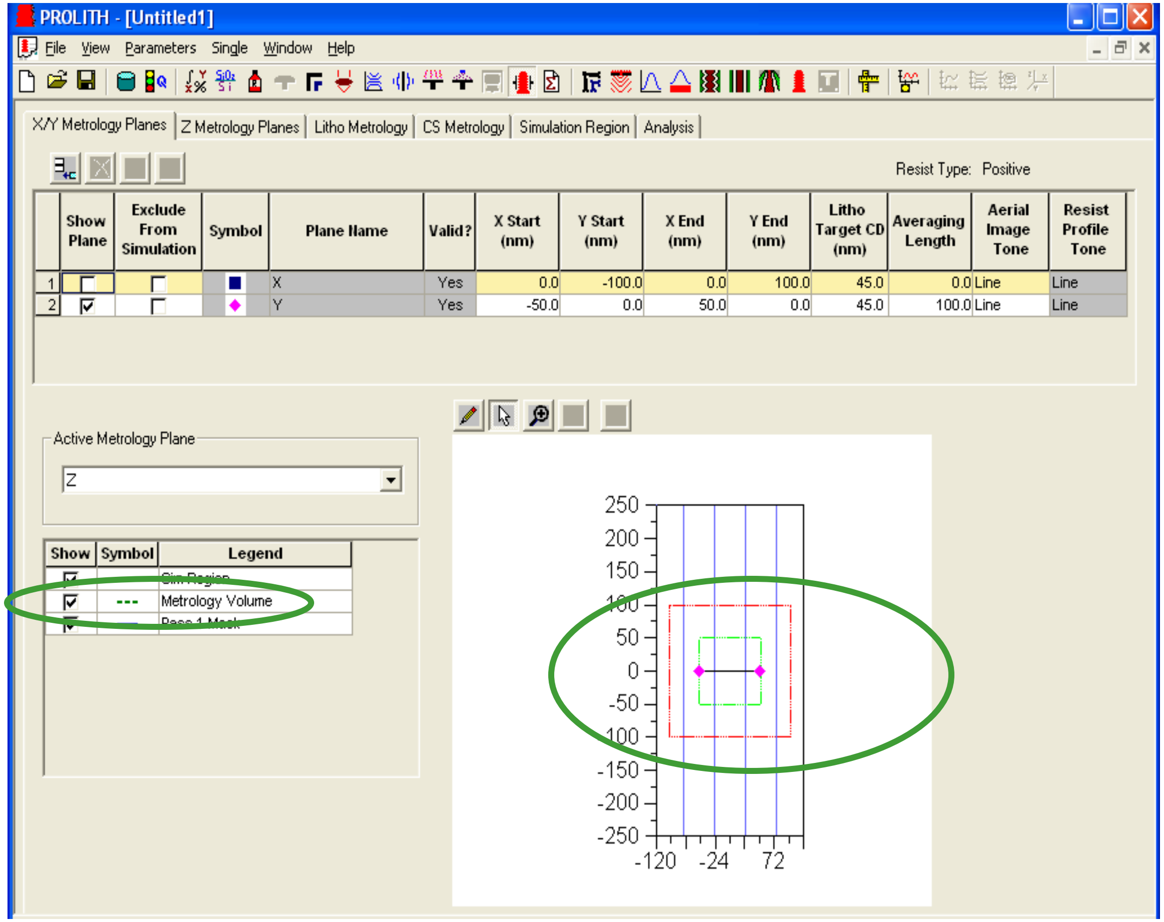
	Show Plane	Exclude From Simulation	Symbol	Plane Name	Valid?	X Start (nm)	Y Start (nm)	X End (nm)	Y End (nm)	Litho Target CD (nm)	Averaging Length	Aerial Image Tone	Resist Profile Tone
1	☐	☐	■	X	Yes	0.0	-100.0	0.0	100.0	45.0	0.0	Line	Line
2	☑	☐	◆	Y	Yes	-50.0	0.0	50.0	0.0	45.0	100.0	Line	Line

Active Metrology Plane: Z

Show	Symbol	Legend
☑	---	Sim Region
☑	---	Metrology Volume
☑	—	Pass 1 Mask

Changes to Metrology Planes – XY Planes
The Metrology Volume

- PROLITH uses the averaging length to form the extents of the *metrology volume*.
- If the averaging length value places any of the metrology volume outside the simulation region , the metrology volume will be invalid.
- This metrology volume is used when output is of a volumetric nature. e.g., p '# of PAGs', '# of quenchers', "# of absorbed photons" or 'Quantum yield'



Resist Type: Positive

	Show Plane	Exclude From Simulation	Symbol	Plane Name	Valid?	X Start (nm)	Y Start (nm)	X End (nm)	Y End (nm)	Litho Target CD (nm)	Averaging Length	Aerial Image Tone	Resist Profile Tone
1	☐	☐	■	X	Yes	0.0	-100.0	0.0	100.0	45.0	0.0	Line	Line
2	☑	☐	◆	Y	Yes	-50.0	0.0	50.0	0.0	45.0	100.0	Line	Line

Active Metrology Plane

Z

Show	Symbol	Legend
☑		Sim Region
☑	---	Metrology Volume
☑		Pass 1 Mask

Changes to Metrology Planes – Z Planes The Averaging Length

- All z planes have an implied (non-editable) averaging length which extends from the lowest point in the resist to the highest.

- The extent of the averaging length is unaffected by the height of the main z –plane (i.e., the averaging length doen’t stay centered on the primary plane as it does on XY planes.

- Consequently, the metrology volume associate with all z-planes is the entire volume of the simulation region.

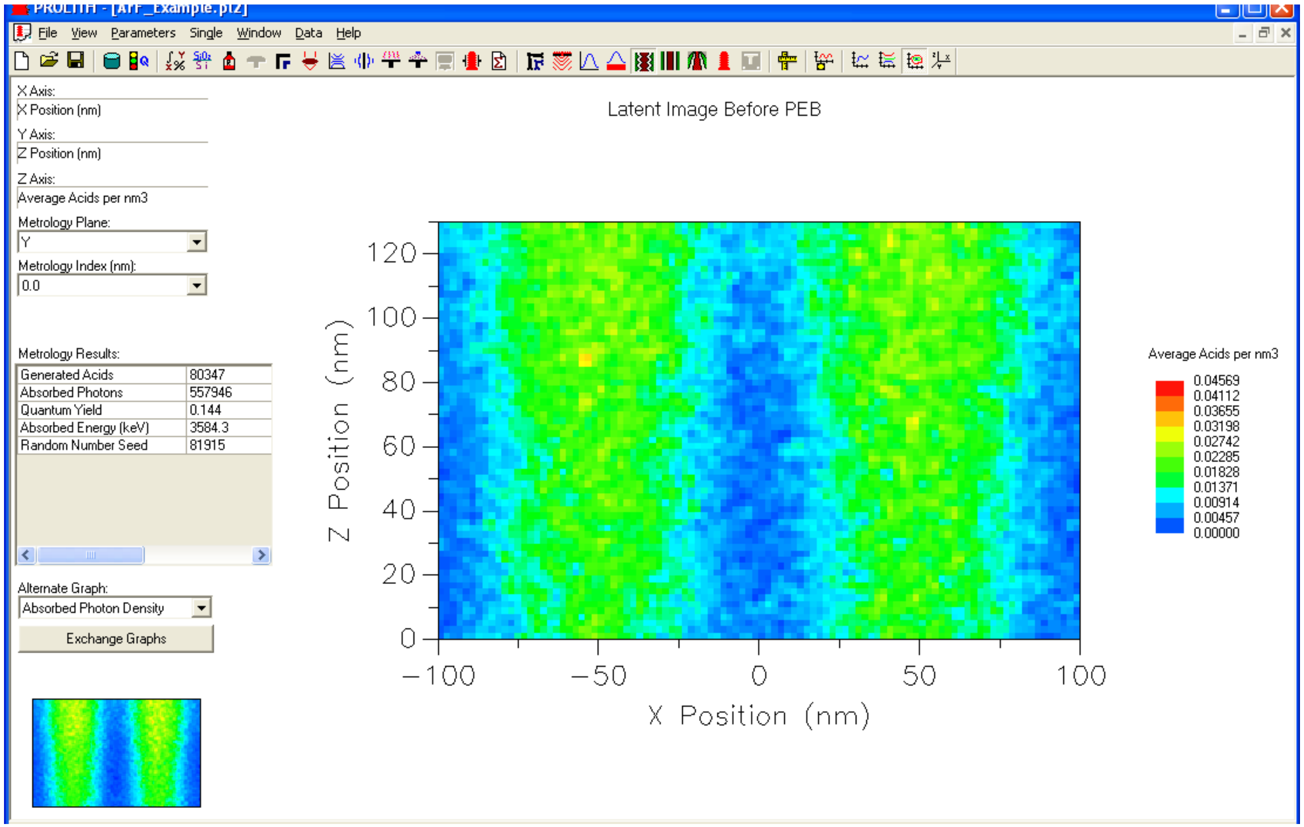
The Advanced Chemically Amplified Resist Model Output screens – Continuum Mode

- In continuum mode, the output data and graphs are essentially the same as standard output for the chemically amplified resist.

- Output graphs are for the main metrology plane (not averaged through the volume).

- On the ‘exposed latent image’ output screen only the acid concentration map is available, it’s unit are altered ‘acids per nm^3’ to reflect the absolute PAG/acid loading used in the advanced chemical amplified model. (The standard chemically amplified model uses a relative PAG/acid loading).

The Advanced Chemically Amplified Resist Model Exposed Latent Image Outputs – Stochastic Mode



X Axis: X Position (nm)

Y Axis: Z Position (nm)

Z Axis: Average Acids per nm3

Metrology Plane: Y

Metrology Index (nm): 0.0

Metrology Results:

Generated Acids	80347
Absorbed Photons	557946
Quantum Yield	0.144
Absorbed Energy (keV)	3584.3
Random Number Seed	81915

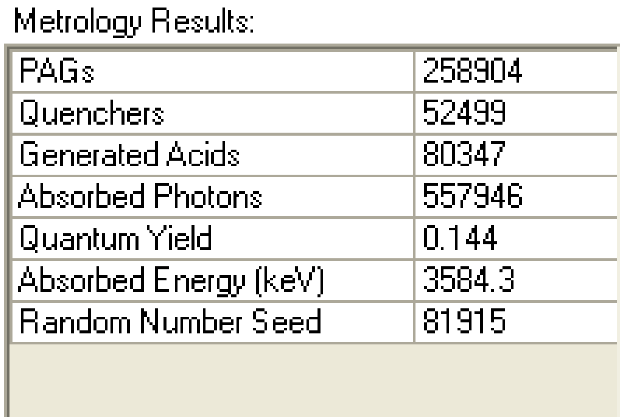
Alternate Graph: Absorbed Photon Density

- The primary graph of the latent image output graph is acid density. This is averaged through the active ‘*metrology volume*’ in the direction of the ‘*averaging length*’.

The Advanced Chemically Amplied Resist Model Exposed Latent Image Outputs – Stochastic Mode

The available numeric output are:

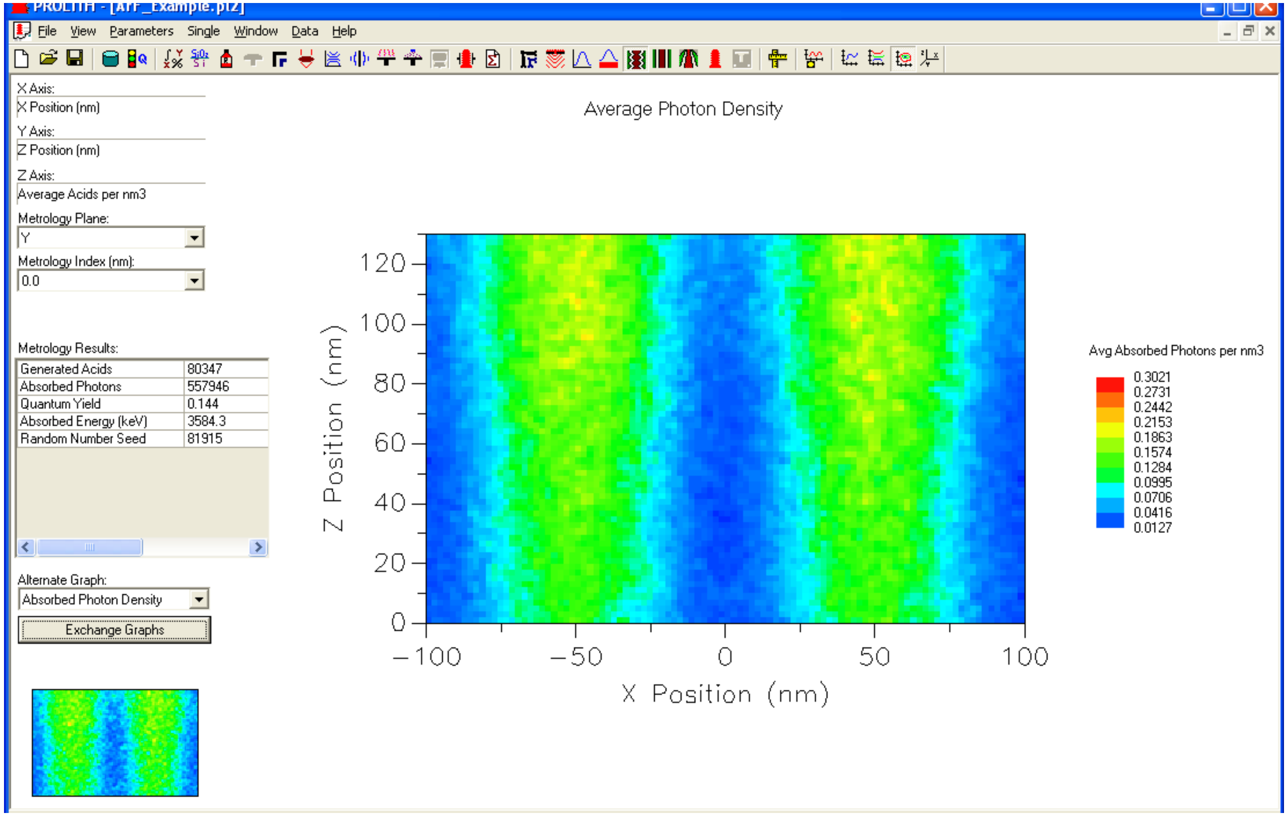
- The number of PAGs in the active metrology volume. (only available when z-plane selected)
- The number of quenchers in the active metrology volume. (only available when z-plane selected)
- The number of photons absorbed in the active metrology volume.
- The number of acids generated in the active metrology volume.
- The overall quantum yield (# of acid/ # of photons absorbed) for the active metrology volume.
- The absorbed energy (KeV) for the active metrology volume



Metrology Results:

PAGs	258904
Quenchers	52499
Generated Acids	80347
Absorbed Photons	557946
Quantum Yield	0.144
Absorbed Energy (keV)	3584.3
Random Number Seed	81915

The Advanced Chemically Amplied Resist Model Exposed Latent Image Outputs – Stochastic Mode



X Axis:
X Position (nm)

Y Axis:
Z Position (nm)

Z Axis:
Average Acids per nm3

Metrology Plane:
Y

Metrology Index (nm):
0.0

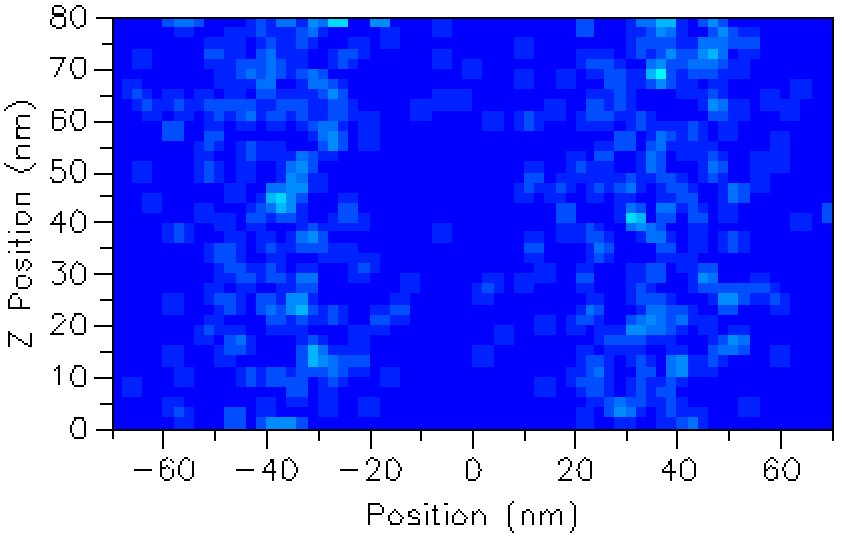
Metrology Results:

Generated Acids	80347
Absorbed Photons	557946
Quantum Yield	0.144
Absorbed Energy (keV)	3584.3
Random Number Seed	81915

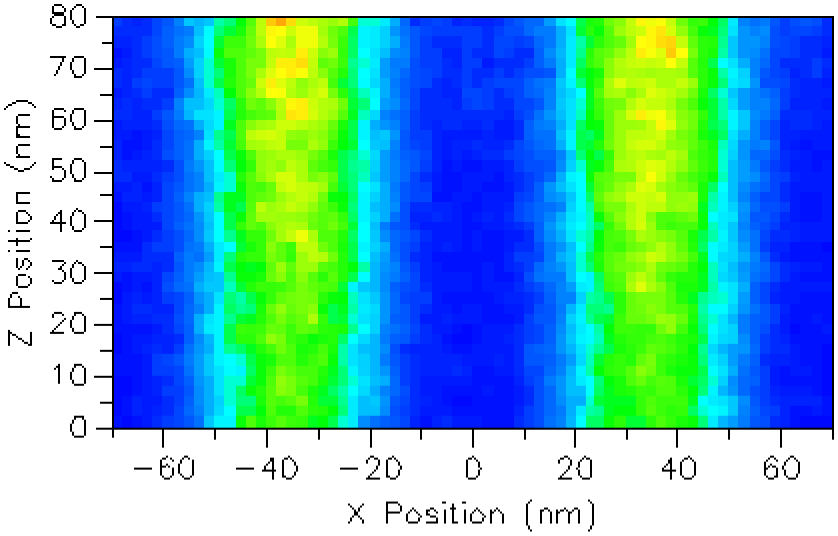
Alternate Graph:
Absorbed Photon Density

- The first alternate graph on the exposed latent image output page is the average photon density for the active ‘metrology volume’ (averaged along the ‘averaging length’).

Why Use Averaged Plots for Photon and Acid Densities?



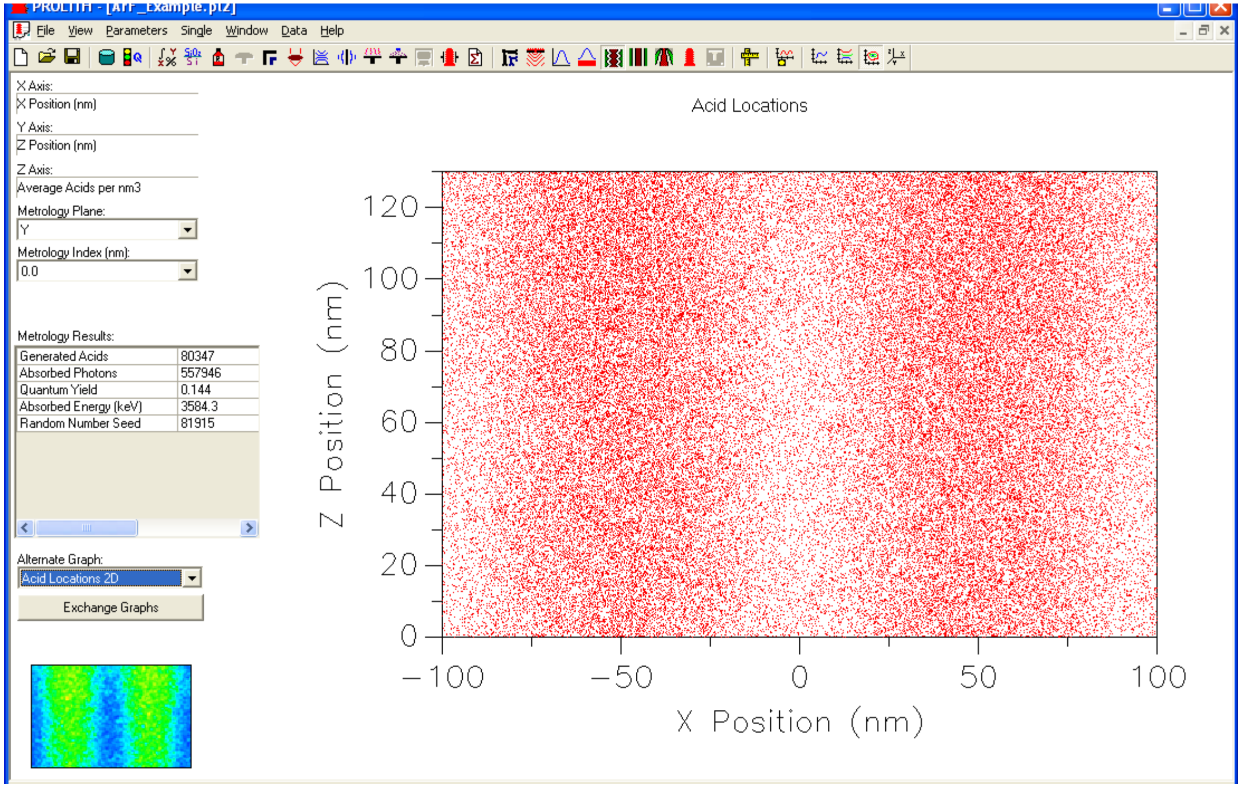
Photon Density
Single Y plane - EUV



Photon Density

Averaged over 250 nm - EUV

The Advanced Chemically Amplied Resist Model Exposed Latent Image Outputs – Stochastic Mode



X Axis: X Position (nm)

Y Axis: Z Position (nm)

Z Axis: Average Acids per nm3

Metrology Plane: Y

Metrology Index (nm): 0.0

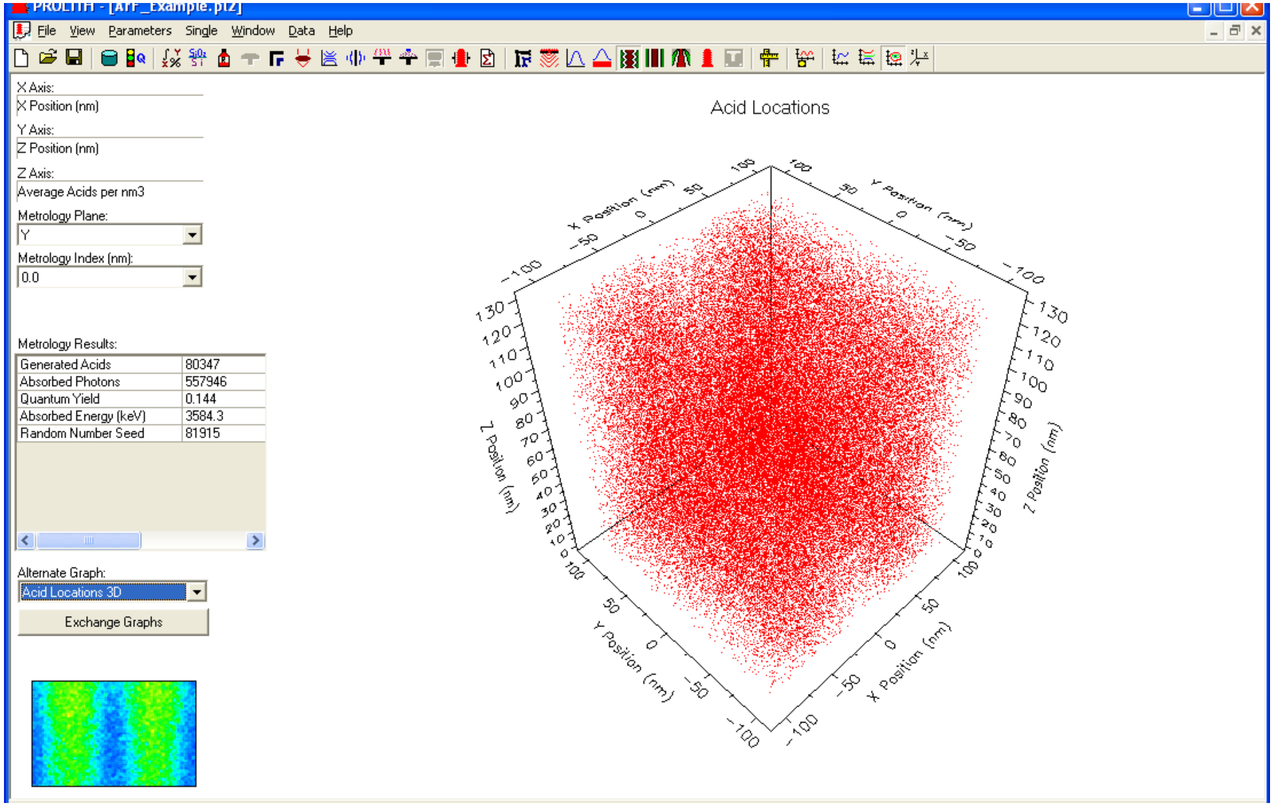
Metrology Results:

Generated Acids	80347
Absorbed Photons	557946
Quantum Yield	0.144
Absorbed Energy (keV)	3584.3
Random Number Seed	81915

Alternate Graph: Acid Locations 2D

- The second alternate graph on the exposed latent image output page is a 2D plot of the acid locations in the metrology volume viewed along the ‘averaging length’ axis. (Only available if ‘# of acids’ < 100,000 for the active volume)

The Advanced Chemically Amplied Resist Model Exposed Latent Image Outputs – Stochastic Mode



X Axis: X Position (nm)

Y Axis: Z Position (nm)

Z Axis: Average Acids per nm3

Metrology Plane: Y

Metrology Index (nm): 0.0

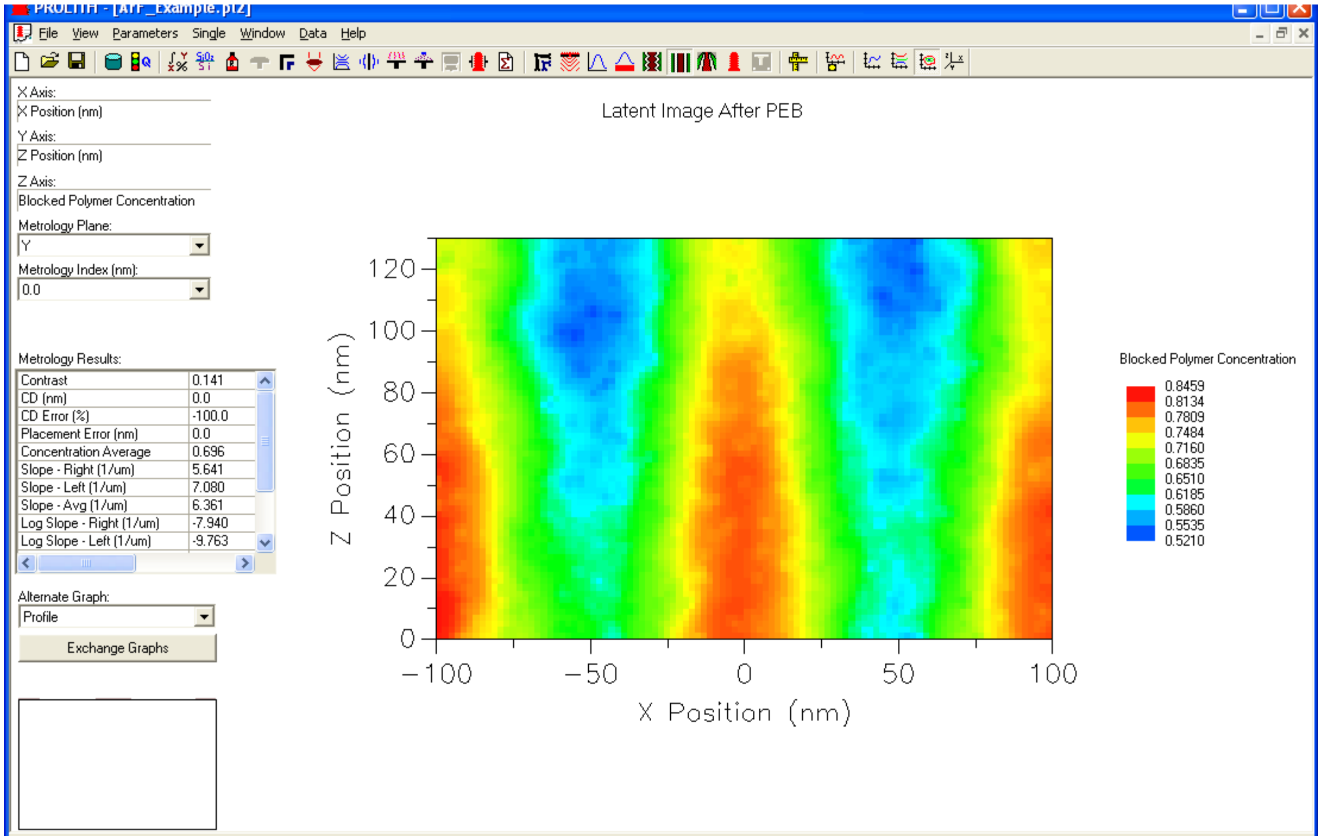
Metrology Results:

Generated Acids	80347
Absorbed Photons	557946
Quantum Yield	0.144
Absorbed Energy (keV)	3584.3
Random Number Seed	81915

Alternate Graph: Acid Locations 3D

- The third alternate graph on the exposed latent image output page is a 3D plot of the acid locations in the metrology volume. (Only available if ‘# of acids’ < 100,000 for the active volume)

The Advanced Chemically Amplified Resist Model PEB Latent Image Outputs – Stochastic Mode



X Axis:
X Position (nm)

Y Axis:
Z Position (nm)

Z Axis:
Blocked Polymer Concentration

Metrology Plane:
Y

Metrology Index (nm):
0.0

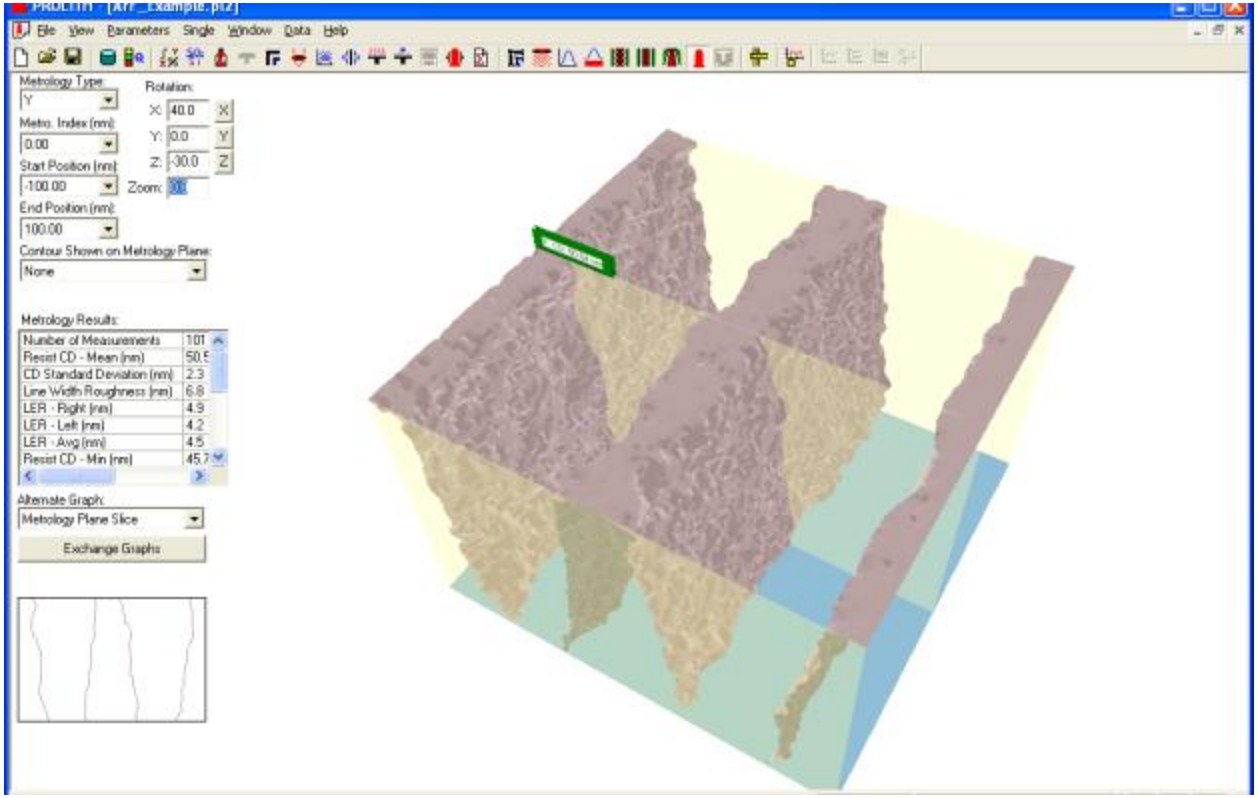
Metrology Results:

Contrast	0.141
CD (nm)	0.0
CD Error (%)	-100.0
Placement Error (nm)	0.0
Concentration Average	0.696
Slope - Right (1/um)	5.641
Slope - Left (1/um)	7.080
Slope - Avg (1/um)	6.361
Log Slope - Right (1/um)	-7.940
Log Slope - Left (1/um)	-9.763

Alternate Graph:
Profile

- The primary graph of the latent image output graph is blocked polymer concentration and is for the primary metrology plane only (not averaged along the line). The numeric outputs are the same as for continuum mode.

The Advanced Chemically Amplified Resist Model
Resist Profile Outputs – Stochastic Mode



Metrology Type: Y

Metro. Index (nm): 0.00

Start Position (nm): -100.00

End Position (nm): 100.00

Contour Shown on Metrology Plane: None

Rotation:
X: 40.0
Y: 0.0
Z: -30.0
Zoom: [illegible]

Metrology Results:

Number of Measurements	101
Resist CD - Mean (nm)	50.5
CD Standard Deviation (nm)	2.3
Line Width Roughness (nm)	6.8
LER - Right (nm)	4.9
LER - Left (nm)	4.2
LER - Avg (nm)	4.5
Resist CD - Min (nm)	45.7

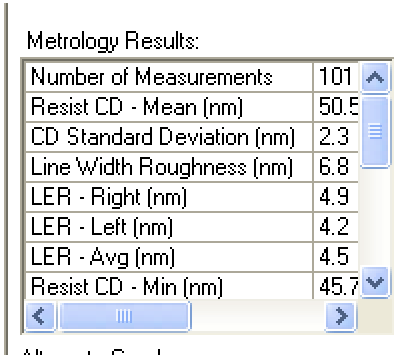
Alternate Graph: Metrology Plane Slice

- Two extra planes are displayed to indicate the ends of the ‘averaging length’
- Movement of the standard planes is restricted, so that the active metrology volume always remains valid.

The Advanced Chemically Amplified Resist Model
Resist Profile Outputs – Stochastic Mode

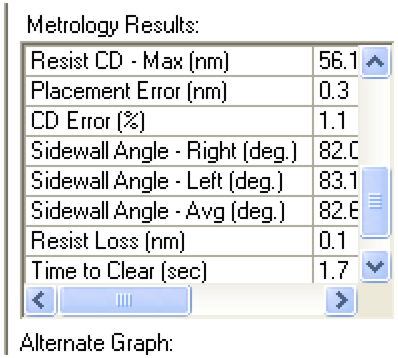
When the averaging length is greater than zero the following numerical outputs are returned:

- Number of measurements in the averaging length
- Mean CD
- Standard deviation (σ) of the CD measurements
- The LWR (3σ)
- The LER values (Left, Right and average)
- The Minimum and Maximum CDs measured
- The average placement error
- The average Sidewall angle and resist loss
- The time to clear for the metrology volume (not averaged)



Metrology Results:

Number of Measurements	101
Resist CD - Mean (nm)	50.5
CD Standard Deviation (nm)	2.3
Line Width Roughness (nm)	6.8
LER - Right (nm)	4.9
LER - Left (nm)	4.2
LER - Avg (nm)	4.5
Resist CD - Min (nm)	45.7

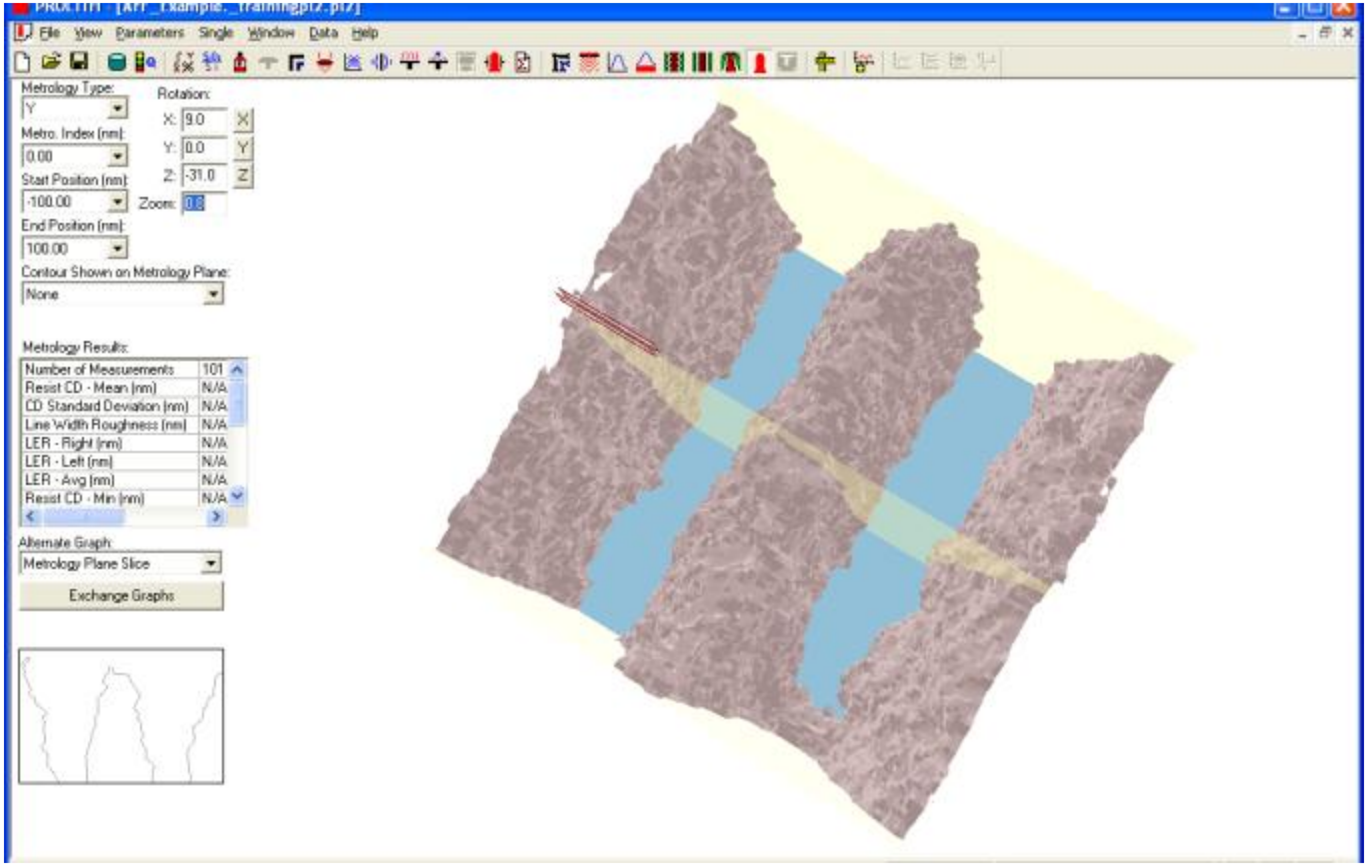


Metrology Results:

Resist CD - Max (nm)	56.1
Placement Error (nm)	0.3
CD Error (%)	1.1
Sidewall Angle - Right (deg.)	82.
Sidewall Angle - Left (deg.)	83.1
Sidewall Angle - Avg (deg.)	82.
Resist Loss (nm)	0.1
Time to Clear (sec)	1.7

Alternate Graph:

The Advanced Chemically Amplified Resist Model
Resist Profile Outputs – Stochastic Mode



Metrology Type: Y

Metro. Index (nm): 0.00

Start Position (nm): -100.00

End Position (nm): 100.00

Contour Shown on Metrology Plane: None

Rotation:
X: 9.0
Y: 0.0
Z: -31.0
Zoom: 0.8

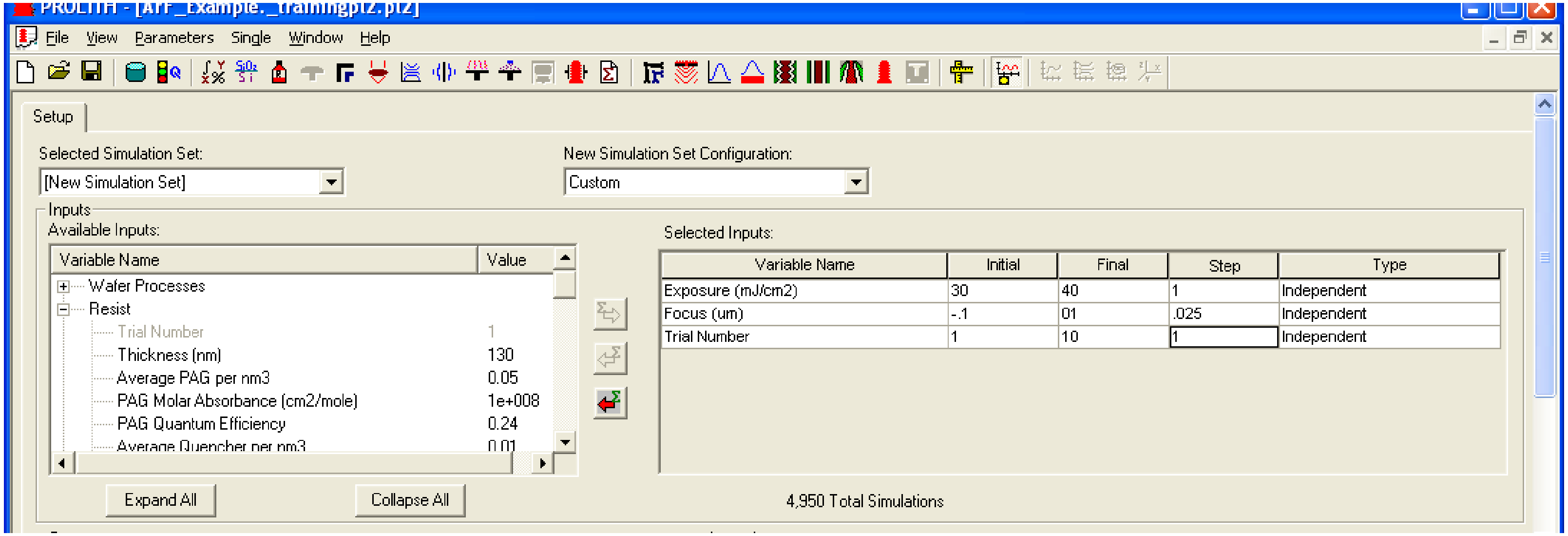
Metrology Results:

Number of Measurements	101
Resist CD - Mean (nm)	N/A
CD Standard Deviation (nm)	N/A
Line Width Roughness (nm)	N/A
LER - Right (nm)	N/A
LER - Left (nm)	N/A
LER - Avg (nm)	N/A
Resist CD - Min (nm)	N/A

Alternate Graph: Metrology Plane Slice

- When feature bridging occurs the average statistics become unavailable (i.e the measurement failed)

The Advanced Chemically Amplified Resist Model Stochastic Mode – Simulation Sets



Selected Simulation Set: [New Simulation Set]

New Simulation Set Configuration: Custom

Inputs

Available Inputs:

Variable Name	Value
Wafer Processes	
Resist	
Trial Number	1
Thickness (nm)	130
Average PAG per nm3	0.05
PAG Molar Absorbance (cm2/mole)	1e+008
PAG Quantum Efficiency	0.24
Average Quencher per nm3	0.01

Selected Inputs:

Variable Name	Initial	Final	Step	Type
Exposure (mJ/cm2)	30	40	1	Independent
Focus (um)	-.1	01	.025	Independent
Trial Number	1	10	1	Independent

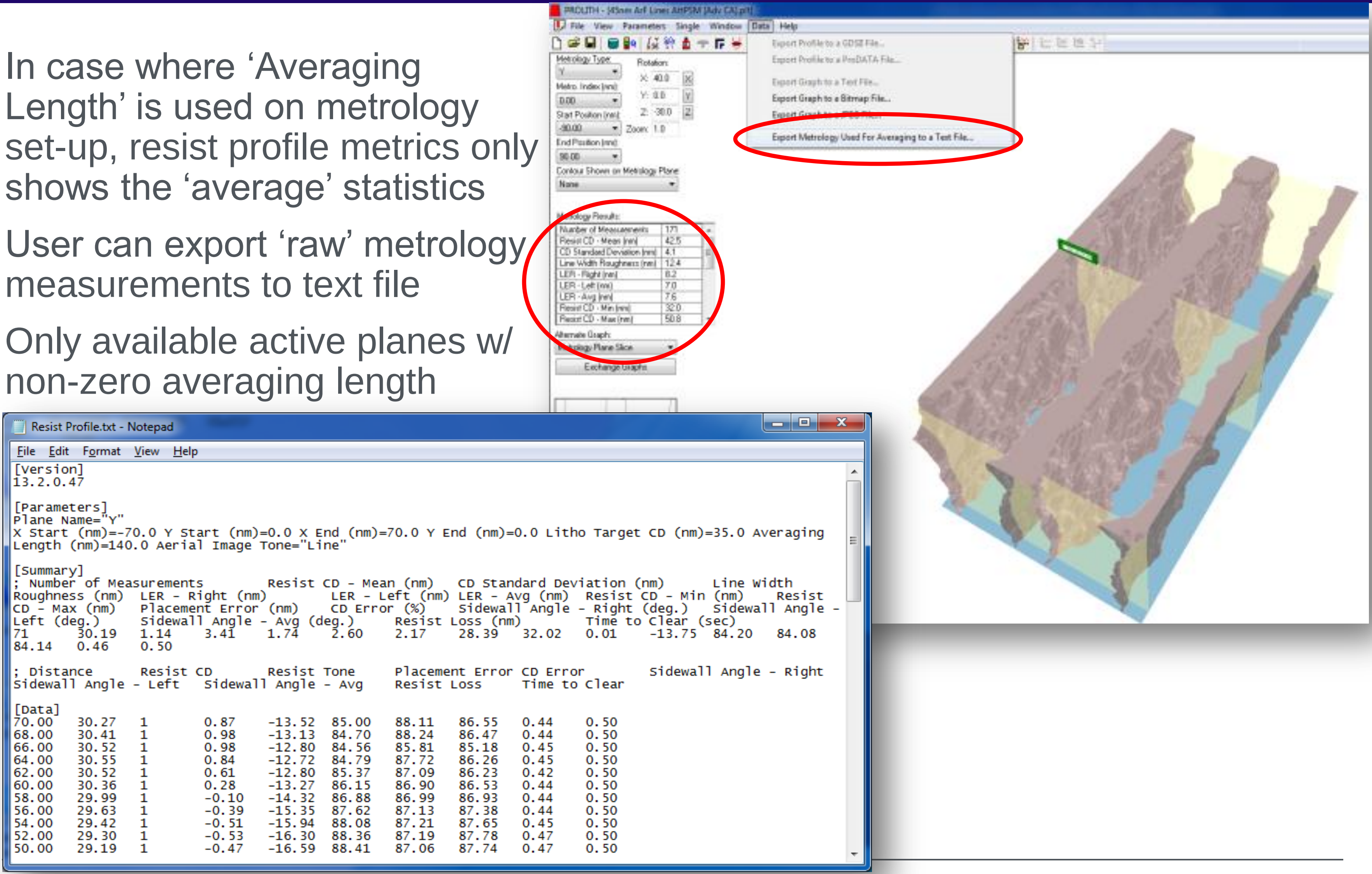
4,950 Total Simulations

- In simulation sets, a new input appears under the resist tab: **Trial Number**
- This allows repeats runs of an experiment to be run with a different outcome each time (provided that the ‘***simulation set increment***’ value on the resist information tab is non-zero).

Metrology Updates

Output individual cut-line data for averaged metrology plane

- In case where ‘Averaging Length’ is used on metrology set-up, resist profile metrics only shows the ‘average’ statistics
- User can export ‘raw’ metrology measurements to text file
- Only available active planes w/ non-zero averaging length



Metrology Type: Y
Metro. Index (nm): 0.00
Start Position (nm): -90.00
End Position (nm): 90.00
Contour Shown on Metrology Plane: None
Rotation: X: 40.0 Y: 0.0 Z: -30.0
Zoom: 1.0

Metrology Results:

Number of Measurements	171
Resist CD - Mean (nm)	42.5
CD Standard Deviation (nm)	4.1
Line Width Roughness (nm)	12.4
LER - Right (nm)	8.2
LER - Left (nm)	7.0
LER - Avg (nm)	7.6
Resist CD - Min (nm)	32.0
Resist CD - Max (nm)	50.8

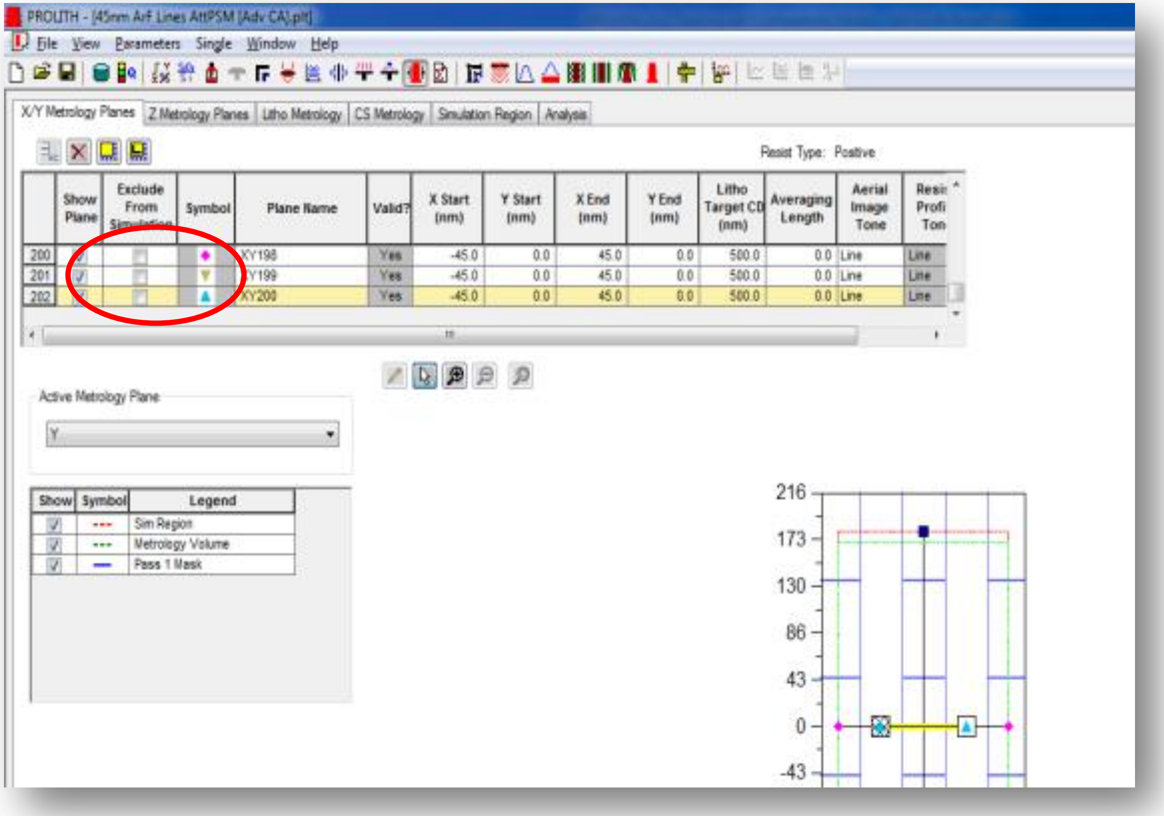
Alternate Graph: Metrology Plane Slice

Resist Profile.txt - Notepad

```
[Version]
13.2.0.47

[Parameters]
Plane Name="Y"
X Start (nm)=-70.0 Y Start (nm)=0.0 X End (nm)=70.0 Y End (nm)=0.0 Litho Target CD (nm)=35.0 Averaging
Length (nm)=140.0 Aerial Image Tone="Line"

[Summary]
; Number of Measurements         Resist CD - Mean (nm)   CD Standard Deviation (nm)       Line Width
Roughness (nm)  LER - Right (nm)        LER - Left (nm) LER - Avg (nm)  Resist CD - Min (nm)     Resist
CD - Max (nm)   Placement Error (nm)    CD Error (%)    Sidewall Angle - Right (deg.)   Sidewall Angle -
Left (deg.)     Sidewall Angle - Avg (deg.)     Resist Loss (nm)        Time to Clear (sec)
71      30.19   1.14    3.41    1.74    2.60    2.17    28.39   32.02   0.01    -13.75  84.20   84.08
84.14   0.46    0.50

; Distance      Resist CD       Resist Tone     Placement Error CD Error        Sidewall Angle - Right
Sidewall Angle - Left   Sidewall Angle - Avg    Resist Loss     Time to Clear

[Data]
70.00   30.27   1       0.87    -13.52  85.00   88.11   86.55   0.44    0.50
68.00   30.41   1       0.98    -13.13  84.70   88.24   86.47   0.44    0.50
66.00   30.52   1       0.98    -12.80  84.56   85.81   85.18   0.45    0.50
64.00   30.55   1       0.84    -12.72  84.79   87.72   86.26   0.45    0.50
62.00   30.52   1       0.61    -12.80  85.37   87.09   86.23   0.42    0.50
60.00   30.36   1       0.28    -13.27  86.15   86.90   86.53   0.44    0.50
58.00   29.99   1       -0.10   -14.32  86.88   86.99   86.93   0.44    0.50
56.00   29.63   1       -0.39   -15.35  87.62   87.13   87.38   0.44    0.50
54.00   29.42   1       -0.51   -15.94  88.08   87.21   87.65   0.45    0.50
52.00   29.30   1       -0.53   -16.30  88.36   87.19   87.78   0.47    0.50
50.00   29.19   1       -0.47   -16.59  88.41   87.06   87.74   0.47    0.50
```

Increased # of user defined planes to 200

of User defined XY metrology planes (2D designs) increased from 20 to 200 in X3.2



Resist Type: Positive

	Show Plane	Exclude From Simulation	Symbol	Plane Name	Valid?	X Start (nm)	Y Start (nm)	X End (nm)	Y End (nm)	Litho Target CD (nm)	Averaging Length	Aerial Image Tone	Resi Profi Ton
200	☑	☐	◆	XY198	Yes	-45.0	0.0	45.0	0.0	500.0	0.0	Line	Line
201	☑	☐	▼	Y199	Yes	-45.0	0.0	45.0	0.0	500.0	0.0	Line	Line
202	☑	☐	▲	XY200	Yes	-45.0	0.0	45.0	0.0	500.0	0.0	Line	Line

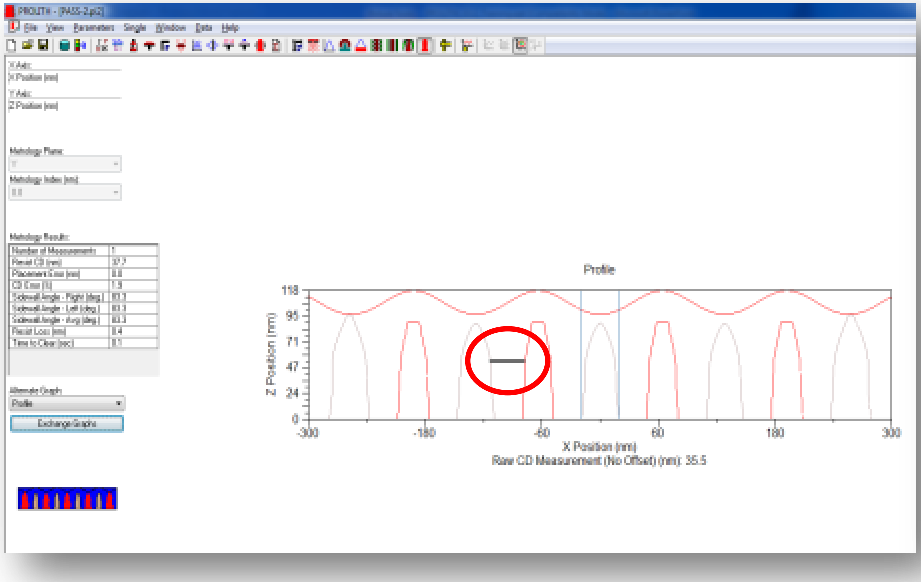
Active Metrology Plane

Y

Show	Symbol	Legend
☑	---	Sim Region
☑	---	Metrology Volume
☑	—	Pass 1 Mask

Measure arbitrary CD

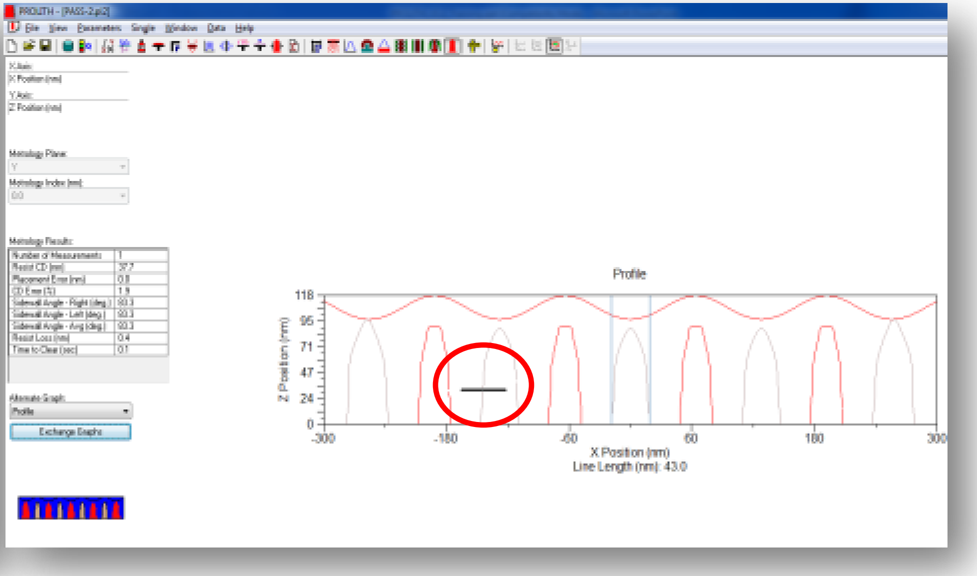
- User can measure distance between any arbitrary polygons on resist profile view
- User can draw and arbitrary line and get the length of the line as well.
- Right click on the graph and use ctrl + drag to draw arbitrary line.
- Right click on graph and use drag to draw line between two edges.
- This is available for 2D Aerial Images as well.
- This is available for 1D and 2D Image in Resist as well as Resist profile window



Metrology Results:

Number of Measurements	1
Resist CD (nm)	37.7
Placement Error (nm)	0.8
CD Error (%)	1.9
Sidewall Angle - Right (deg.)	80.3
Sidewall Angle - Left (deg.)	80.3
Sidewall Angle - Avg (deg.)	80.3
Resist Loss (nm)	0.4
Time to Clear (sec)	0.1

Raw CD Measurement (No Offset) (nm): 35.5



Metrology Results:

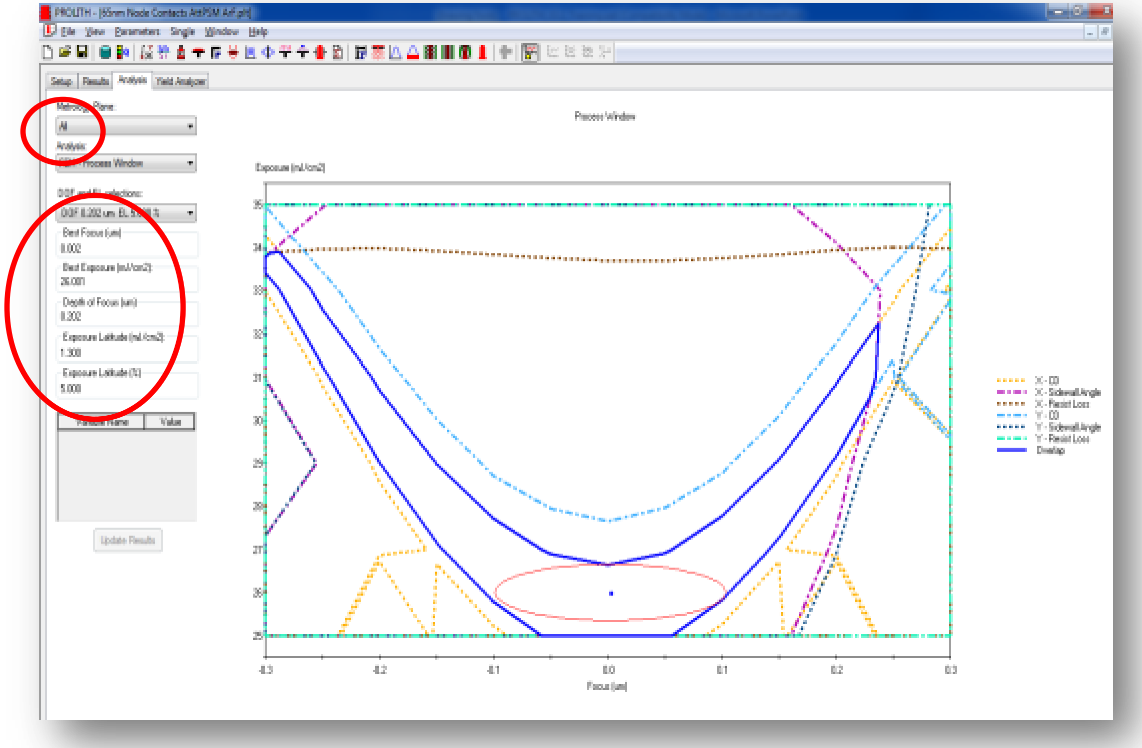
Number of Measurements	1
Resist CD (nm)	37.7
Placement Error (nm)	0.8
CD Error (%)	1.9
Sidewall Angle - Right (deg.)	80.3
Sidewall Angle - Left (deg.)	80.3
Sidewall Angle - Avg (deg.)	80.3
Resist Loss (nm)	0.4
Time to Clear (sec)	0.1

Line Length (nm): 43.0

PPI Update

Overlap Process Window Metrics using PPI

- ALL XY metrology plane provides the overlap process window metrics on GUI
- Same metrics are now available through PPI
- EL vs. DOF plot for cut-line specific PW as well as overlap PW are also available through PPI now
- Until X3.2, ‘ALL’ metrology plane PW metrics were only available through GUI



Metrology Plane: All

Analysis: Process Window

DOF and EL selections: DOF 0.202 um EL 5.000 %

Best Focus (um): 0.002

Best Exposure (mJ/cm2): 26.001

Depth of Focus (um): 0.202

Exposure Latitude (mJ/cm2): 1.300

Exposure Latitude (%): 5.000

MATLAB Example to get Overlap PW Metrics

```
%Set sim engine object
prolith = COM.Prolith.Application;
document = prolith.ActiveDocument;
MySimEngine = invoke(document, 'SimulationEngine');

%Add simulation set inputs for Focus and Exposure
invoke(MySimEngine, 'AddInput', 29101, 20, 60, 4, 0);
invoke(MySimEngine, 'AddInput', 29102, -1.5, 1.5, 0.25, 0);

%Add simulation set output for Resist Feature Width, CD
invoke(MySimEngine, 'AddOutput', 21);

%Run simulation asynchronously and wait for results to be available
invoke(MySimEngine, 'SimulationRun');

while invoke(MySimEngine, 'IsDataSetReady') == 0;
    pause(0.2)
end

%Get analysis results
retVal.BestFocus = get(MySimEngine, 'BestFocus');
retVal.BestExposure = get(MySimEngine, 'BestExposure');
retVal.DepthOfFocus = get(MySimEngine, 'DepthOfFocus');
retVal.ELAbsolute = get(MySimEngine, 'ExposureLatitudeAbsolute');
retVal.ELPercent = get(MySimEngine, 'ExposureLatitudePercent');

retVal.OverlapBestFocus = get(MySimEngine, 'OverlapBestFocus');
retVal.OverlapBestExposure = get(MySimEngine, 'OverlapBestExposure');
retVal.OverlapDepthOfFocus = get(MySimEngine, 'OverlapDepthOfFocus');
retVal.OverlapELAbsolute = get(MySimEngine, 'OverlapExposureLatitudeAbsolute');
retVal.OverlapELPercent = get(MySimEngine, 'OverlapExposureLatitudePercent');

retVal.ELvsDOF = invoke(MySimEngine, 'GetELvsDOF', 'X');
retVal.OverlapELvsDOF = invoke(MySimEngine, 'GetOverlappingELvsDOF');
```

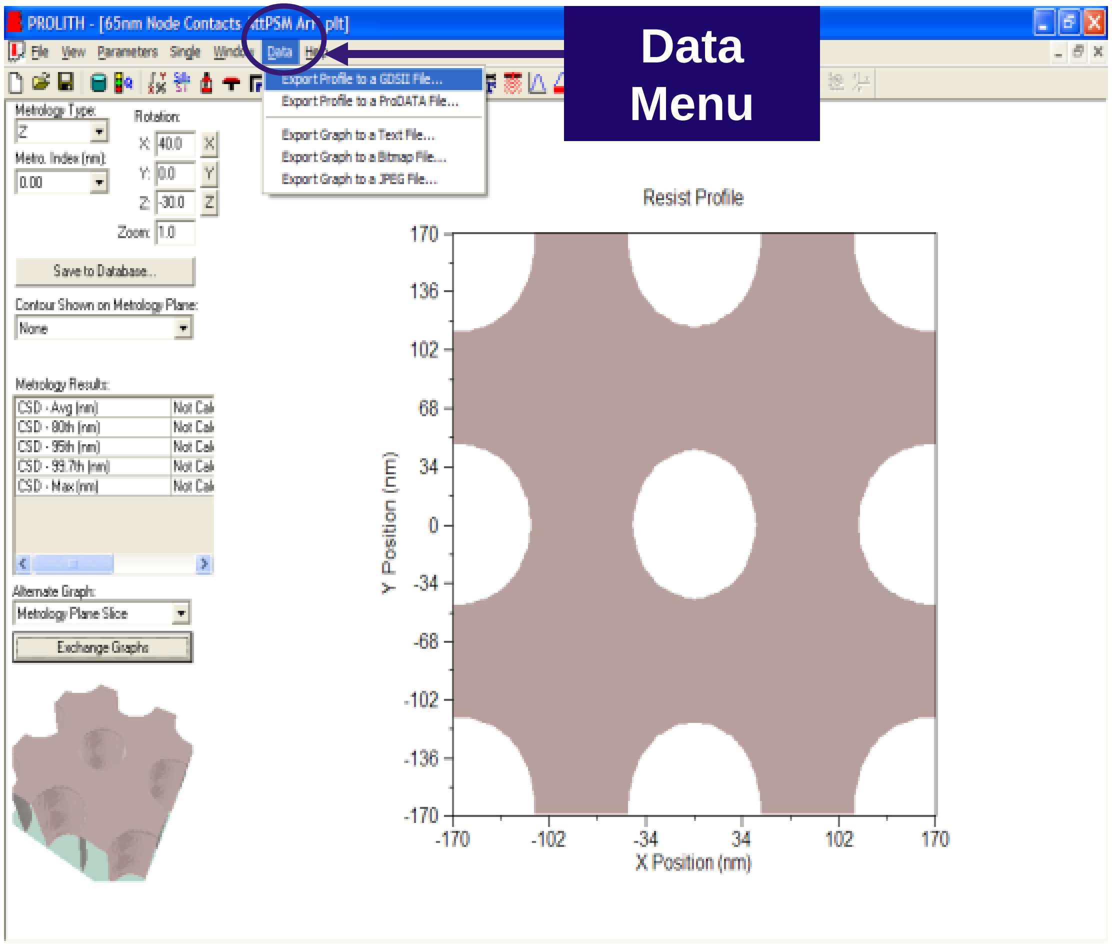
Export GDS Contours

Feature details

- User can now export top down (Z contours) in GDS format

- Contours can be exported from all output views
  - Aerial Image,
  - Image in Resist
  - Latent Images
  - Resist profile contours

Export GDS file from 'Data' menu



Data Menu

Metrology Type: Z

Metro. Index (nm): 0.00

Rotation:
X: 40.0
Y: 0.0
Z: -30.0
Zoom: 1.0

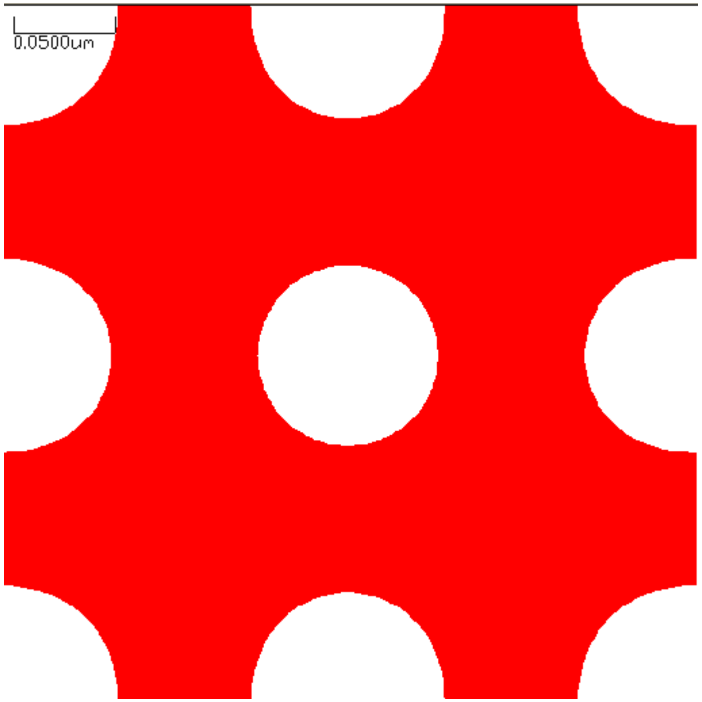
Contour Shown on Metrology Plane: None

Metrology Results:

CSD - Avg (nm)	Not Cal
CSD - 80th (nm)	Not Cal
CSD - 95th (nm)	Not Cal
CSD - 99.7th (nm)	Not Cal
CSD - Max (nm)	Not Cal

Alternate Graph: Metrology Plane Slice

GDS Output



GDS write out precision is 0.001 nm