GenISys
Advancing the Standard

GenISys Team
Nov 18th, 2020

Proximity Effect in E-Beam Lithography

Overview and Agenda

BEAMER LAB TRACER ProSEM MASKER

Webinar Outline

Part	Subject	Date
1	Electron Scattering and Proximity Effect	07-Oct-2020, 6:00pm CEST, 12:00pm EDT, 9:00am PDT
2	Dose PEC Algorithm and Parameter	14-Oct-2020, 6:00pm CEST, 12:00pm EDT, 9:00am PDT
3	Optimization of Dose PEC Parameter	21-Oct-2020, 6:00pm CEST, 12:00pm EDT, 9:00am PDT
4	Process Effect, Calibration and Correction	28-Oct-2020, 5:00pm CET, 12:00pm EDT, 9:00am PDT
5	Shape PEC – "ODUS" Contrast Enhancement	04-Nov-2020, 6:00pm CET, 12:00pm EST, 9:00am PST
	Break	11-Nov-2020 -- No Session
6	3D Surface PEC for Grayscale Lithography	18-Nov-2020, 6:00pm CET, 12:00pm EST, 9:00am PST
	Thanksgiving Week	25-Nov-2020 -- No Session
7	3D T-Gate and Edge PEC for multilayer resist	02-Dec-2020, 6:00pm CET, 12:00pm EST, 9:00am PST

- The webinar series will explain one of the most important techniques in advanced e-beam lithography. Modern E-beam systems are able to form small spot sizes in nm range. In principle this enables to achieve feature sizes in nm-range. In practice this is limited by physics, chemistry and tool limitations…

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Rick Bojko, Uli Hofmann

Nov 18, 2020

Proximity Effect in E-Beam Lithography

Part 6: 3D Surface PEC for Grayscale Lithography

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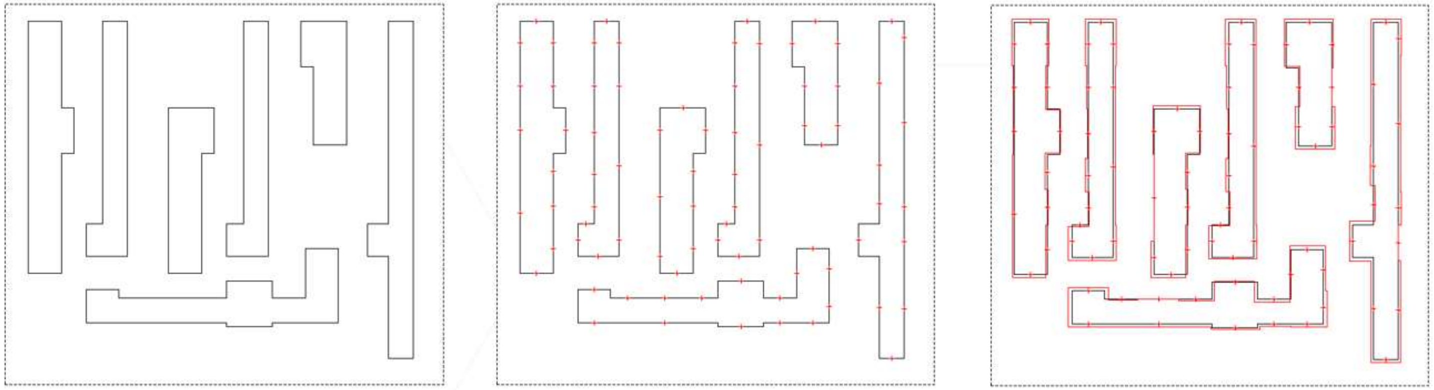
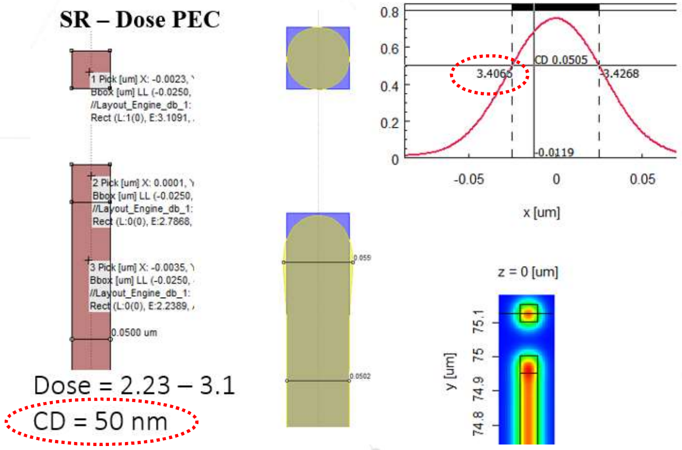
Outline

- Part 5 Summary: Shape PEC – ODUS Contrast Enhancement
- Introduction to 3D Lithography
- 3D-PEC for E-Beam Lithography
- 3D-PEC for Laser Lithography
- Summary

Dose vs. Shape PEC

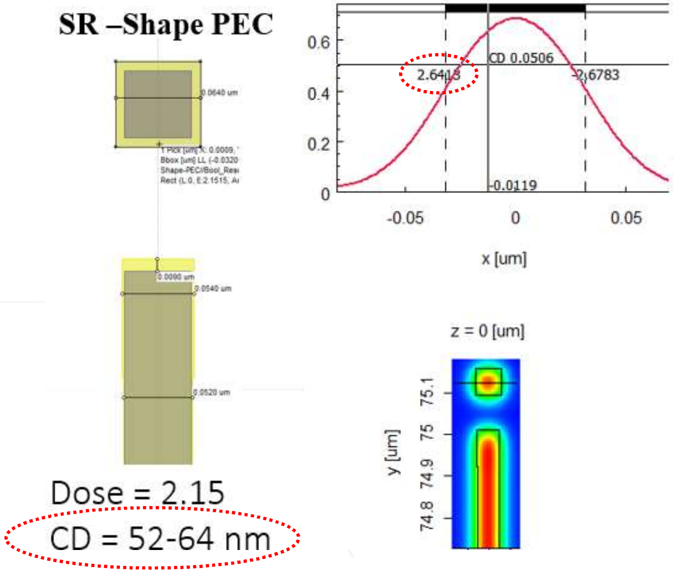
- Long Range (back-scatter) effect is compensated by dose
  - Back-scatter as a „dose error“ should be compensated by dose
- Short- and mid-range effects may be compensated by dose or shape
  - Dose : Higher contrast, more stable for complex shapes, not optimal for non-symetric scenario (e.g. line end, different distance at edges)
  - Shape: Enables non-symmetric correction, BUT: typically lower contrast (without ODUS), limitation for complex curved shapes





SR – Dose PEC

Dose = 2.23 – 3.1
CD = 50 nm

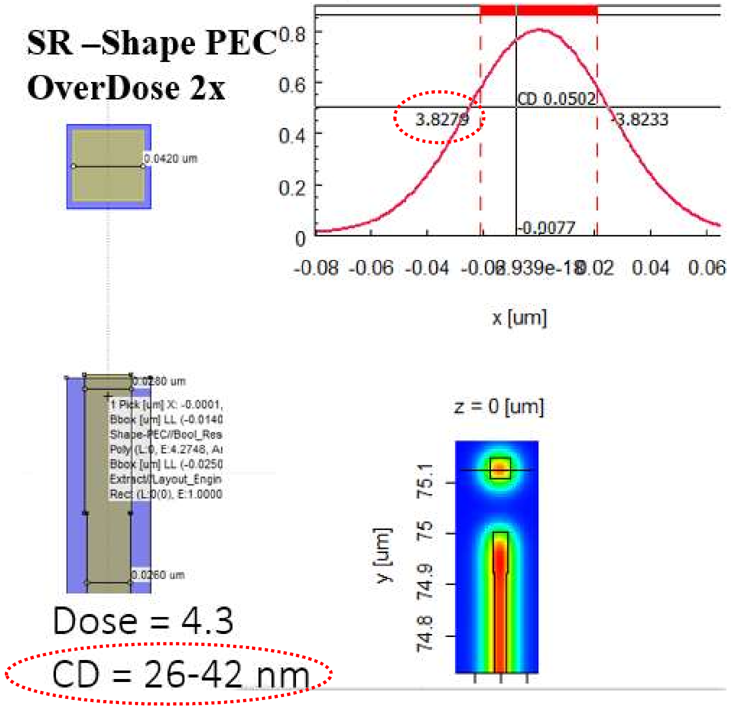


SR –Shape PEC

Dose = 2.15
CD = 52-64 nm

OverDose + UnderSize (ODUS)

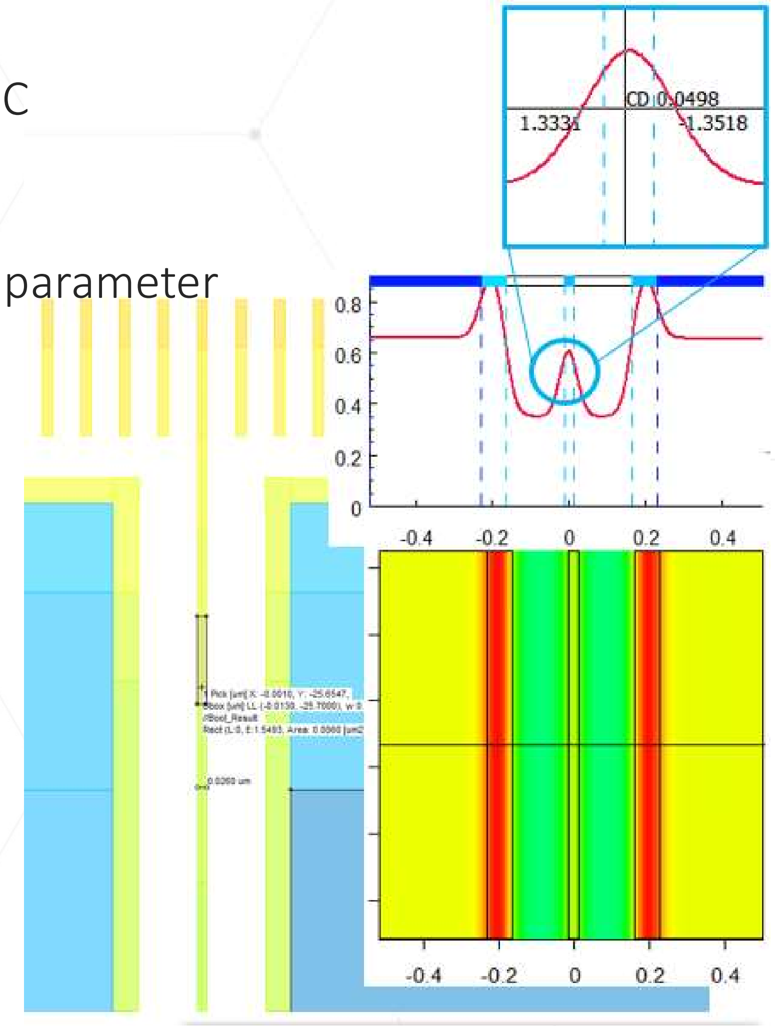
- Benefit 1: Better Image Contrast
  - Enables image contrast (litho quality) beyond Dose PEC
  - Higher edge quality, steeper resist profile
  - More stable process (larger process window)
  - Accurate correction requires Process Blur as essential parameter



SR –Shape PEC
OverDose 2x

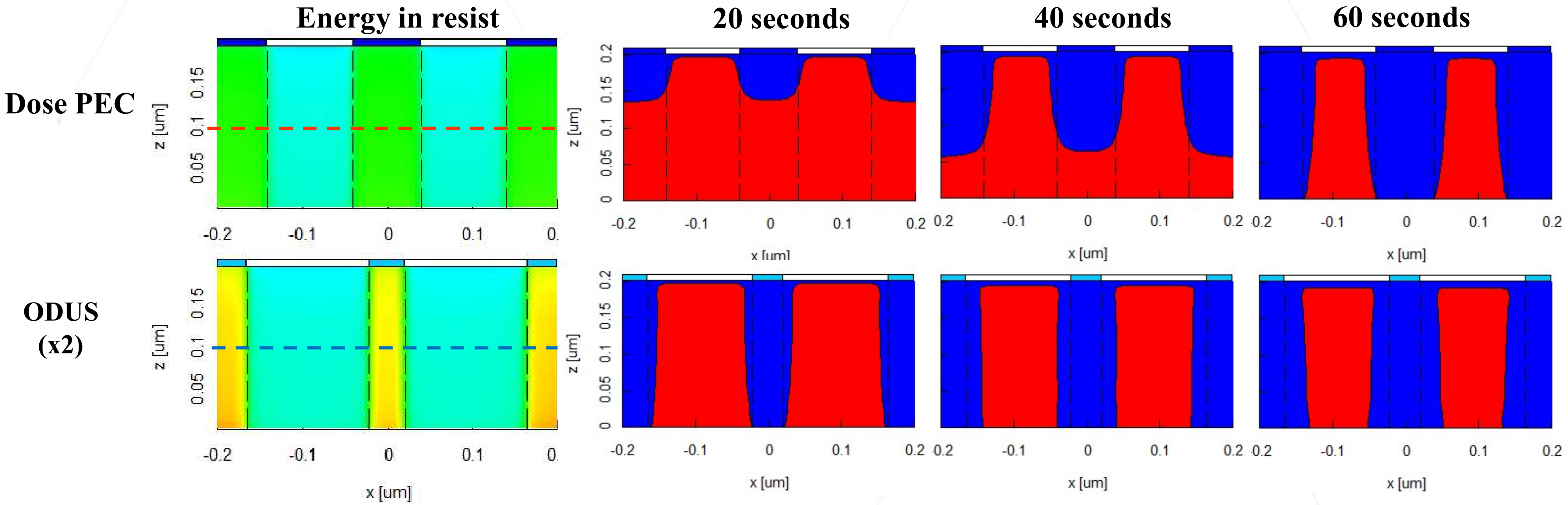
Dose = 4.3

CD = 26-42 nm

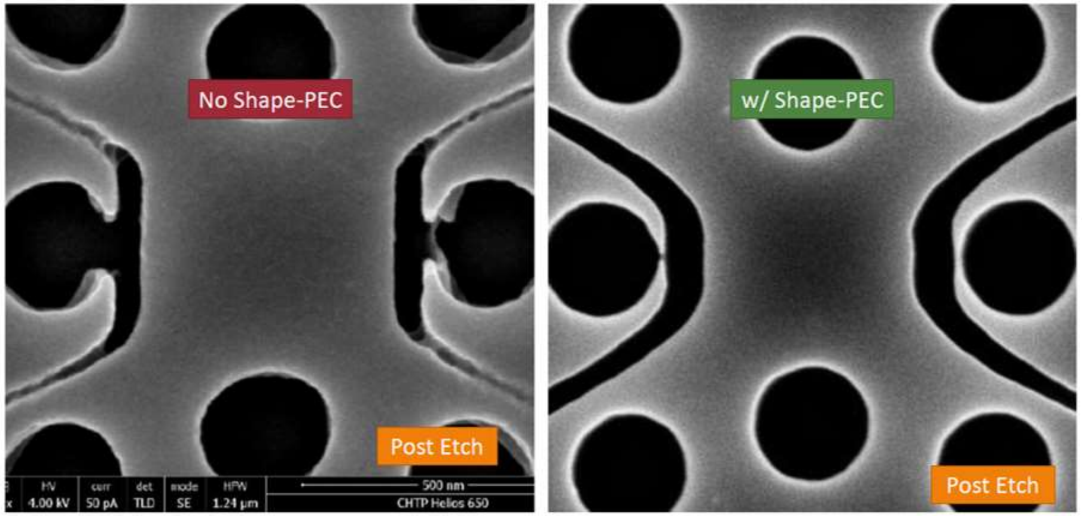


OverDose + UnderSize (ODUS)

- Benefit 2: Resist Sidewall Angle
  - Higher development rates (from overdose) changes development dynamics
  - Undercut larger with thicker resists
  - Undercut larger with higher-Z materials (e.g. GaAs)

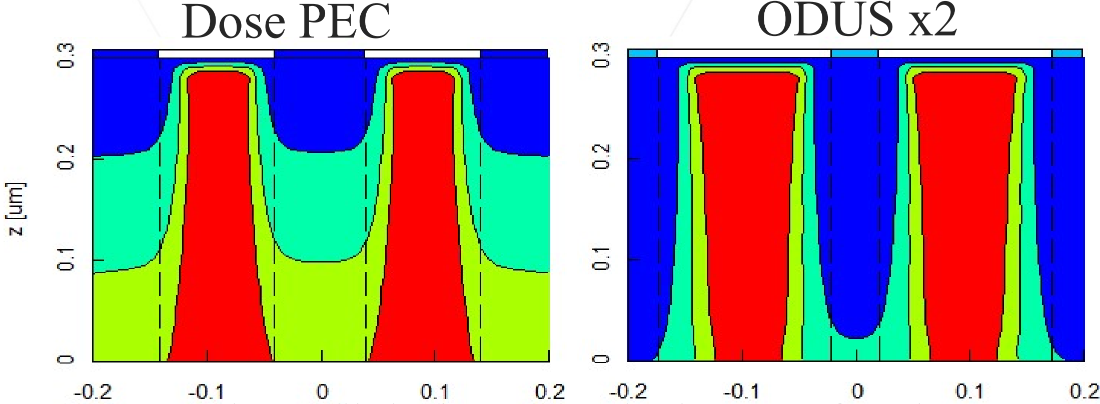


ODUS Application Examples

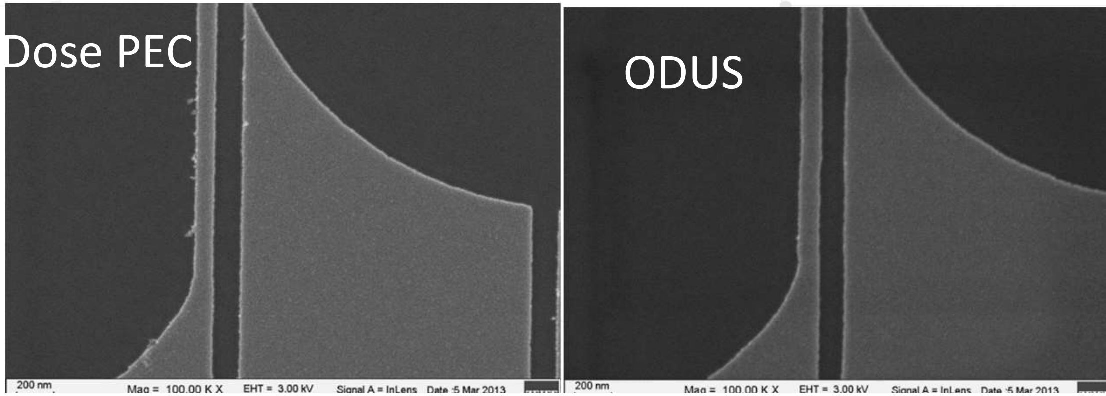


University of British Columbia

Resolving feature & gap sizes on the order of the blur
ZEP 520A on Si @ 100keV
Courtesy: University of British Columbia



Resist Profile in dense scenario for GaAs @100keV



Single layer lift-off process, negative resist profile improvement
PMMA on GaAs @100keV
Courtesy: Weizmann Institute

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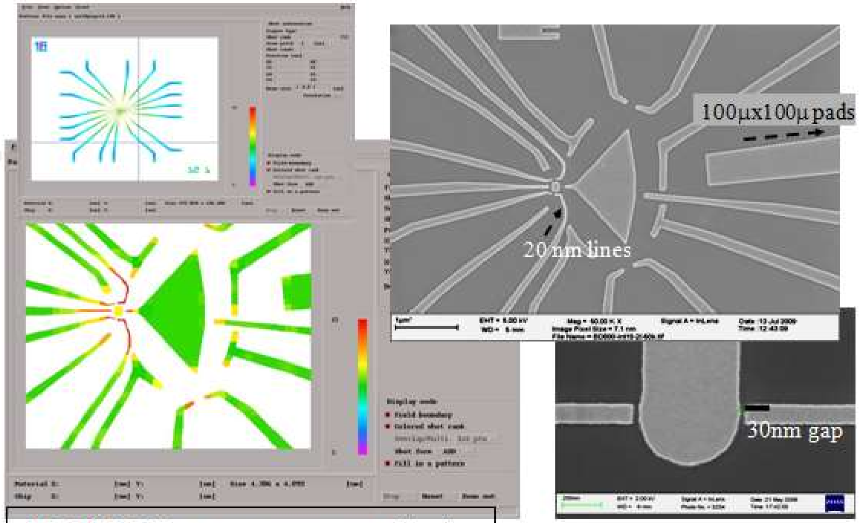
2D Lithography (Earlier Webinars)

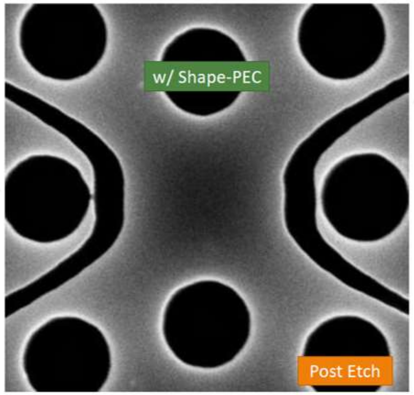
Dose PEC



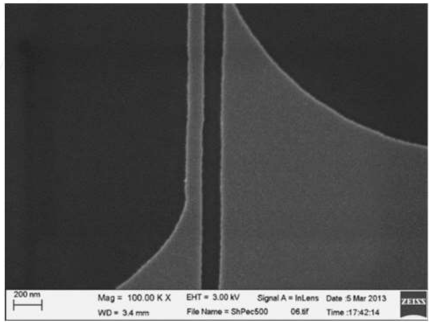
100kV Exposure on GaAs

Source: Weizmann Institute

Shape PEC
ODUS

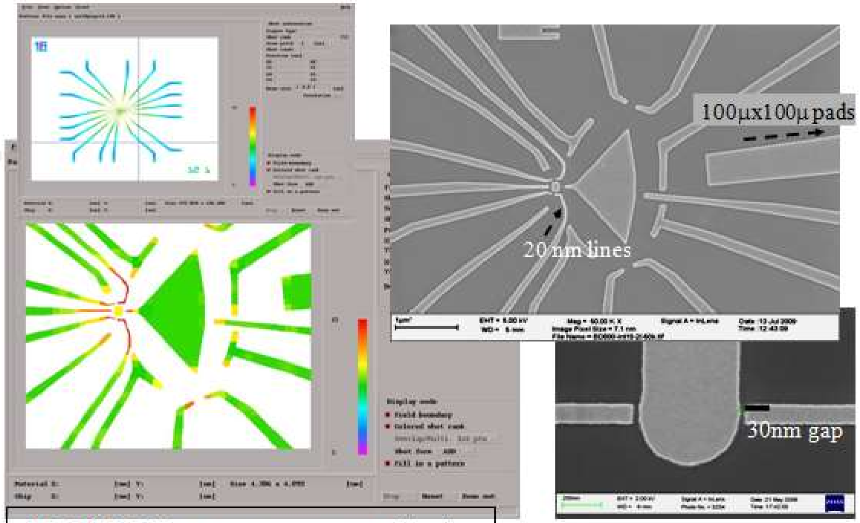


University of British Columbia



2D Lithography (Earlier Webinars)

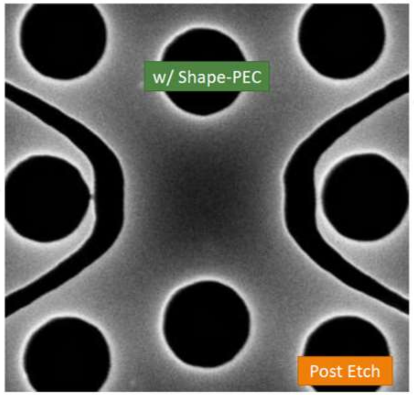
Dose PEC



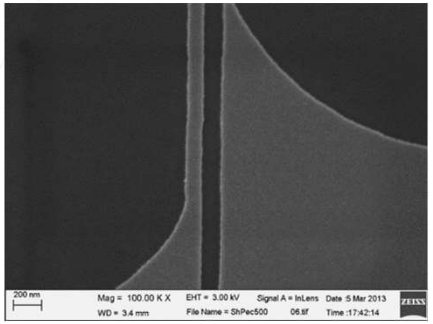
100kV Exposure on GaAs

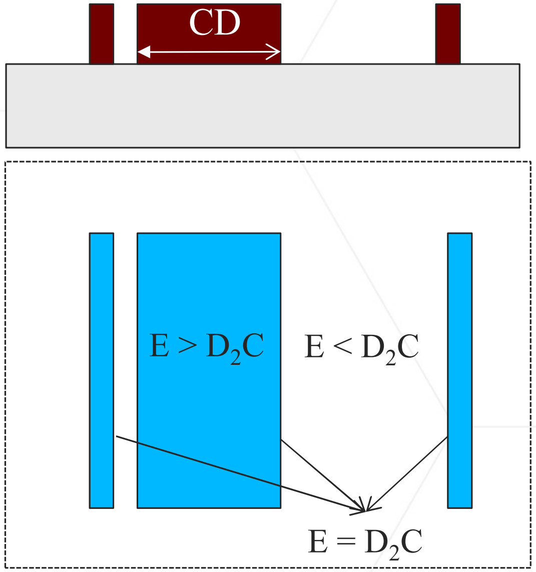
Source: Weizmann Institute

Shape PEC
ODUS



University of British Columbia





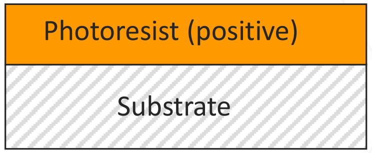
2D Correction Target:

- Require absorbed energy at all feature edges to have same value (Dose to Clear)
- Consequence
  - Absorbed Energy inside features > Dose to Clear
  - Absorbed Energy outside features < Dose to Clear

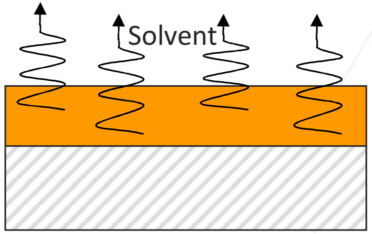
2D Litho vs. 3D Litho

Preprocessing

Cleaning, Baking,
Adhesion Promoter



Spin or Spray Coating

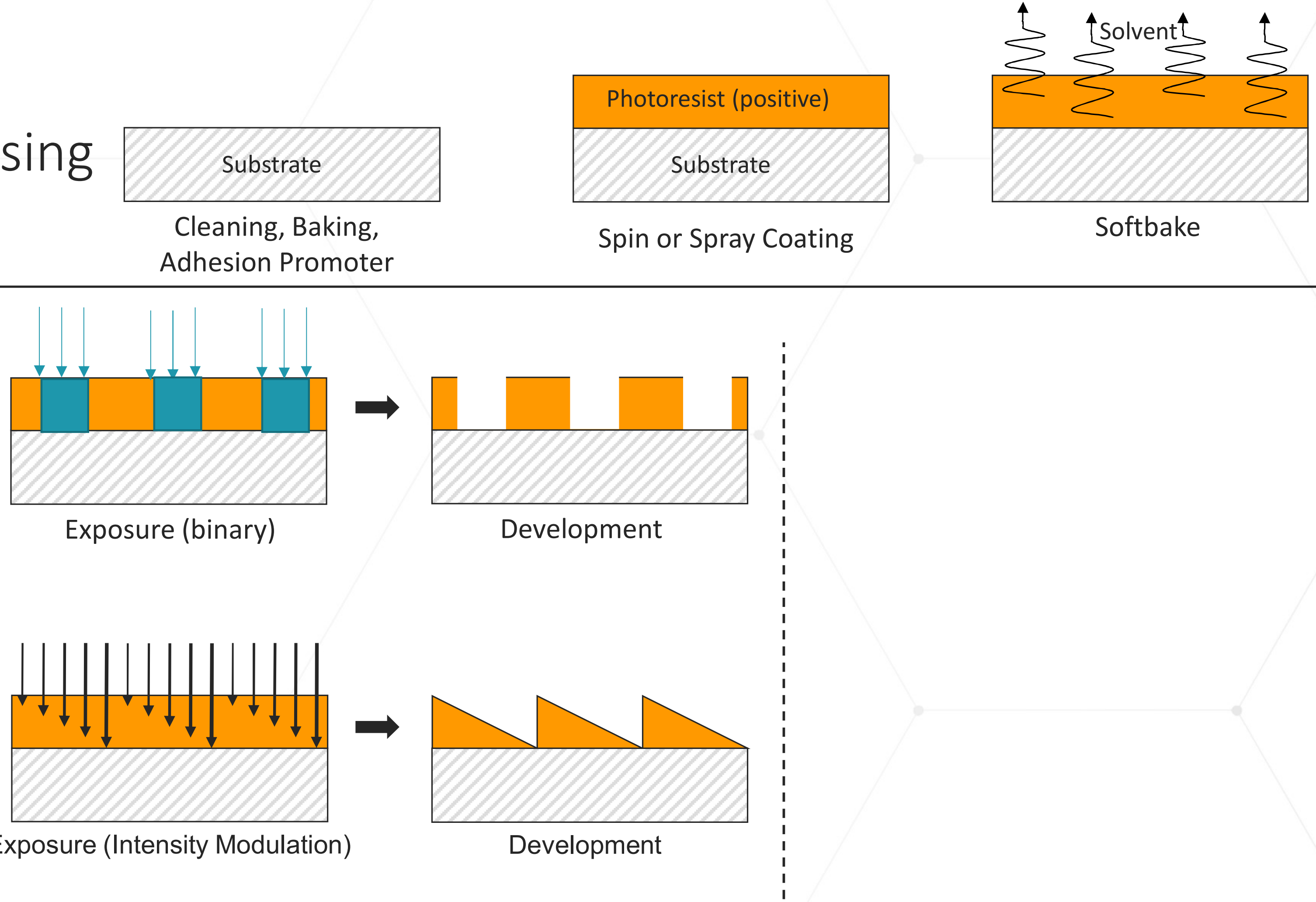


Softbake

2D Litho

3D Litho

2D Litho vs. 3D Litho



Preprocessing

Cleaning, Baking, Adhesion Promoter

Spin or Spray Coating

Softbake

2D Litho

Exposure (binary)

Development

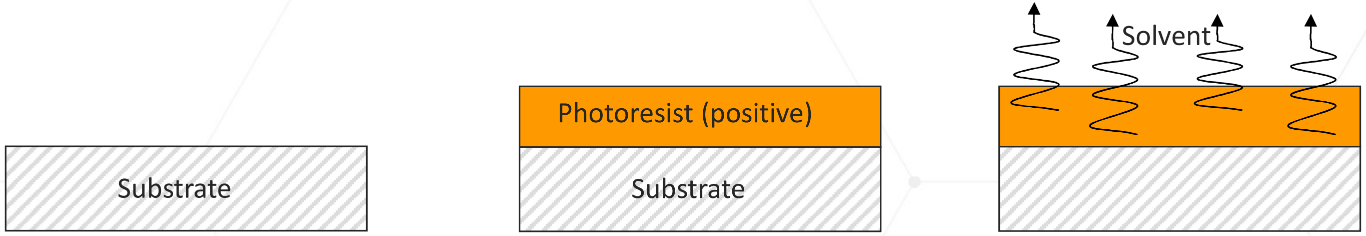
3D Litho

Exposure (Intensity Modulation)

Development

2D Litho vs. 3D Litho

Preprocessing



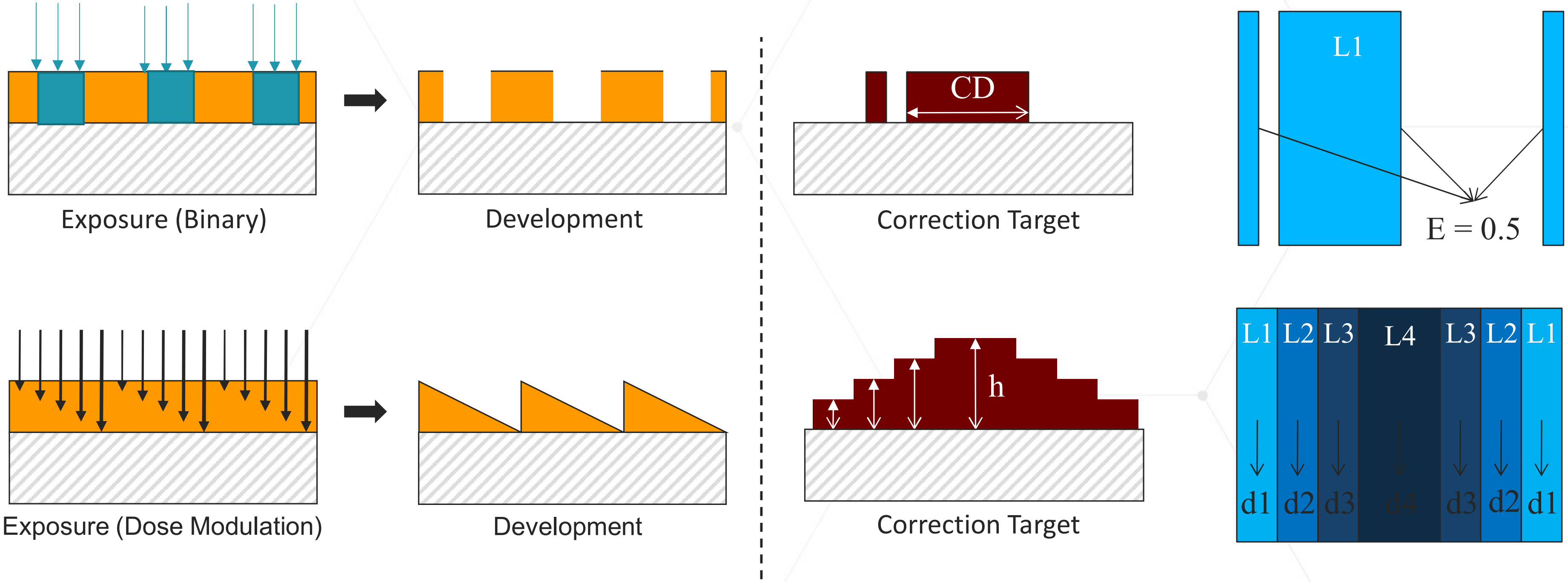
Cleaning, Baking, Adhesion Promoter

Spin or Spray Coating

Softbake

2D Litho

3D Litho



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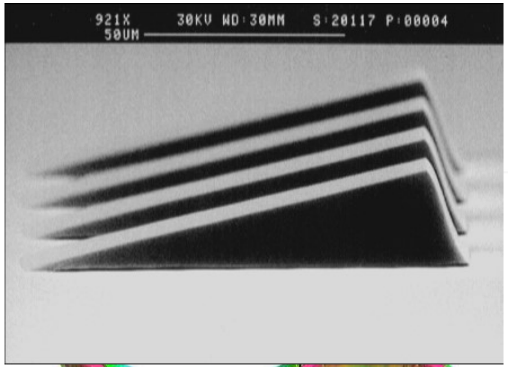
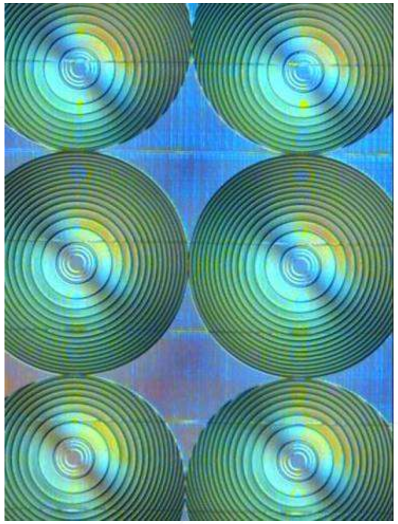
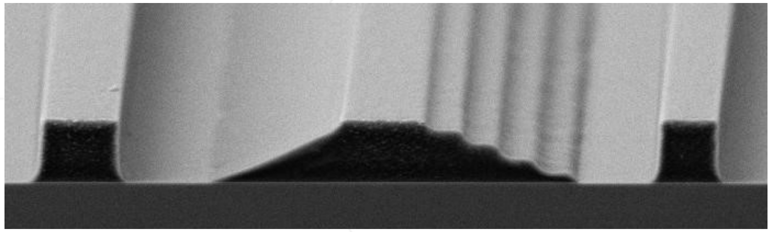
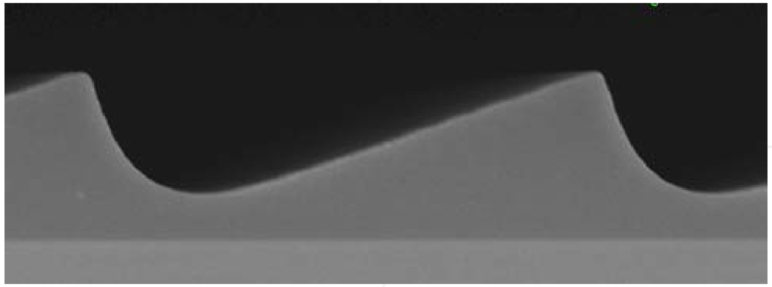
3D Grayscale Lithography

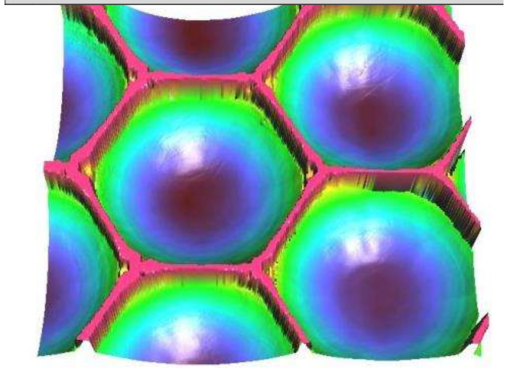


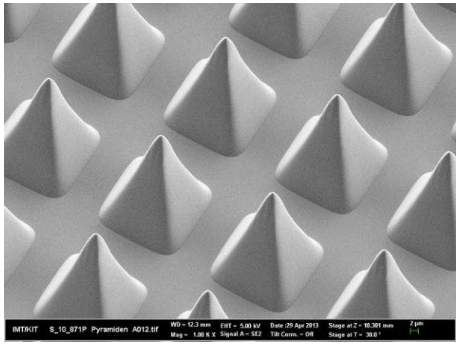


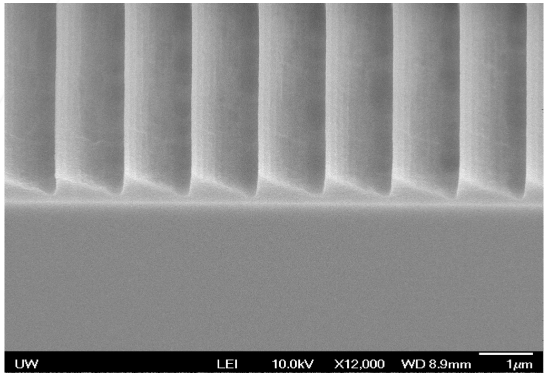
- Micro Lenses
- Lens Arrays
- Blazed Gratings
- Holograms
- Integrated Optics
- Prisms
- MEMS

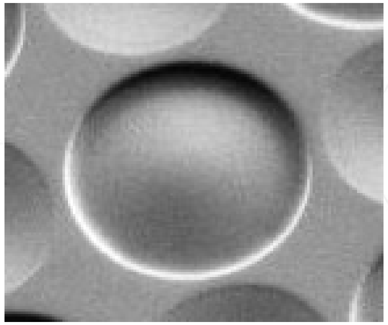


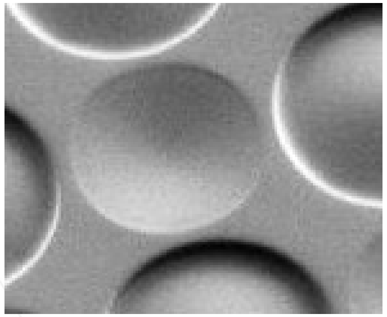












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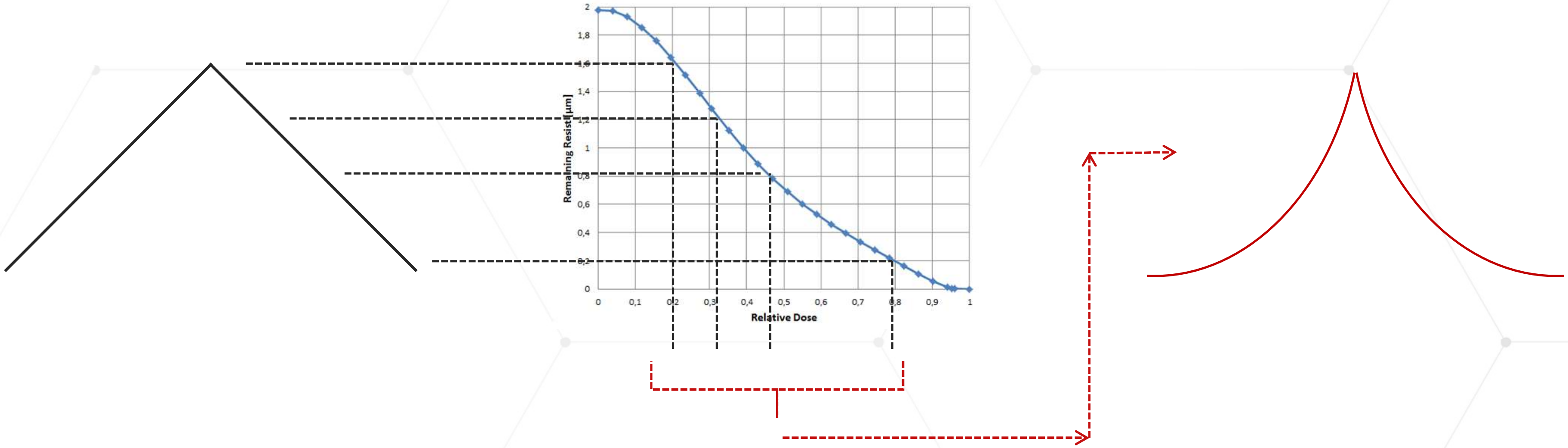
Starting Point: Target Dose Assignment

Target Shape

Contrast Curve

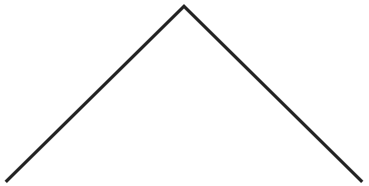
Dose Assignment

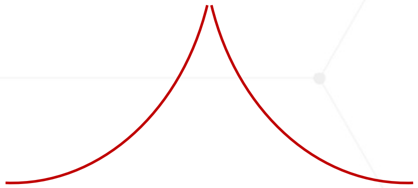


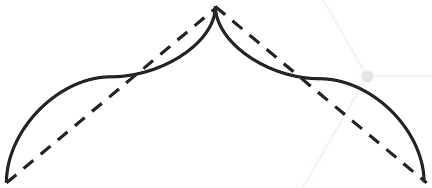
- Would this „starting point“ get us the desired shape?

Starting Point: Target Dose Assignment

- Unlikely to get the designed result:
  - Electron Scattering blurs the energy
  - Lateral Development shifts the feature edges

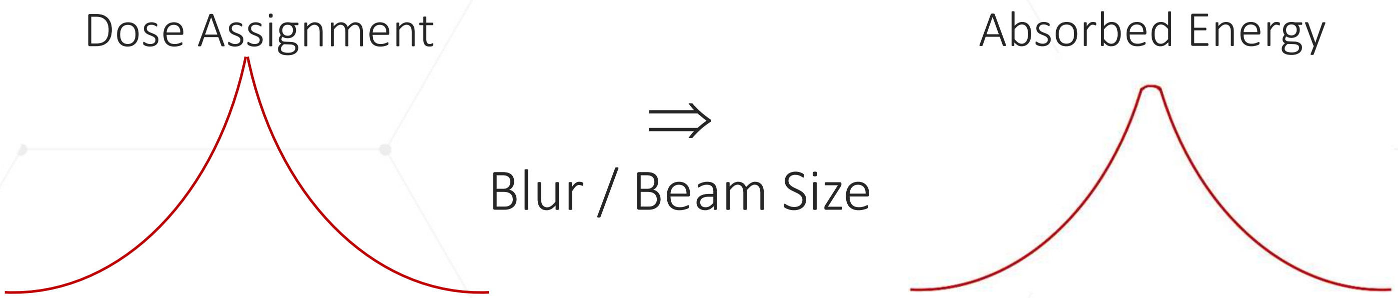

Target Shape


Contrast Curve Dose


Resulting Profile

- Possible Paths:
  - Experimental: Iterate Exposure, Measure, Adjust Exposure, Repeat
  - Computational: Model Effects and Compute Compensation

Blur & Scattering



Dose Assignment

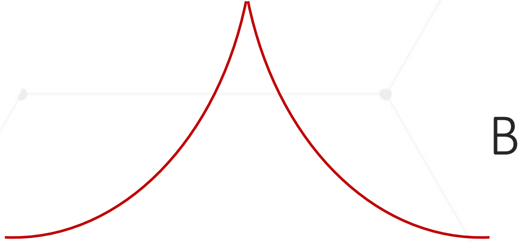
⇒

Blur / Beam Size

Absorbed Energy

Blur & Scattering

Dose Assignment



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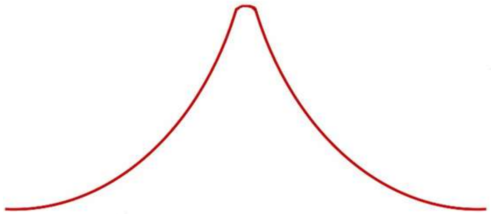
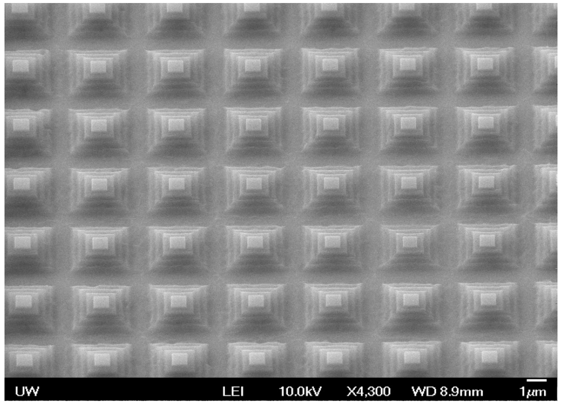
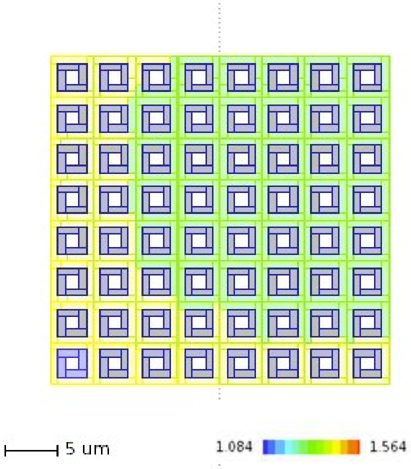
Blur / Beam Size

Absorbed Energy



Add Backscattering Compensation



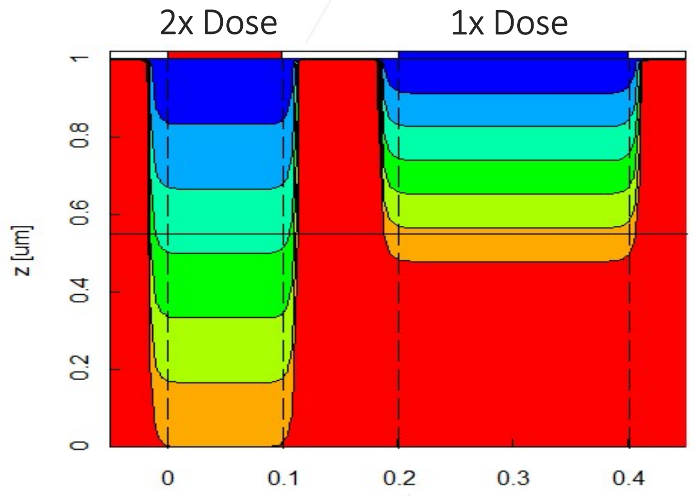


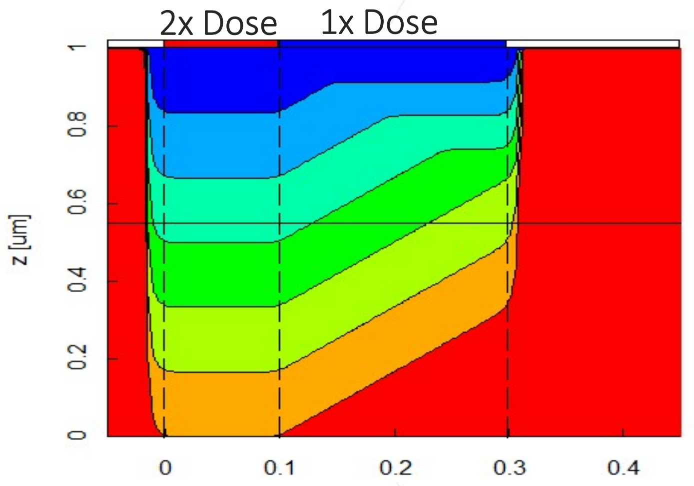
Absorbed Energy is not what you expose / expect. PEC is necessary.

Lateral Development

- Isolated shapes develop independently, with development rate depending on exposure dose

- When regions of different dose are adjacent, as in 3D lithography, the regions have a large interaction, and lateral development correction is essential if you want the correct height in each

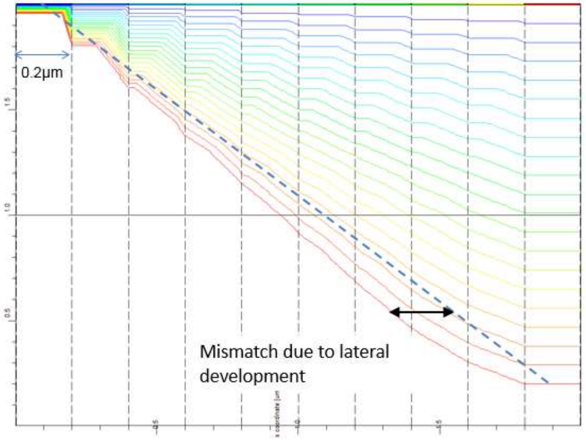




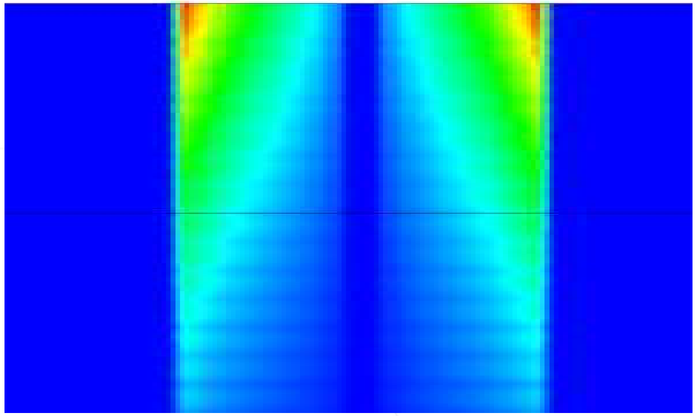
Lateral Development

Absorbed energy defines dissolution rate

- The 3D development front over is modeled over development time
- Since there is absorbed energy “everywhere”
  - The development front does not stop

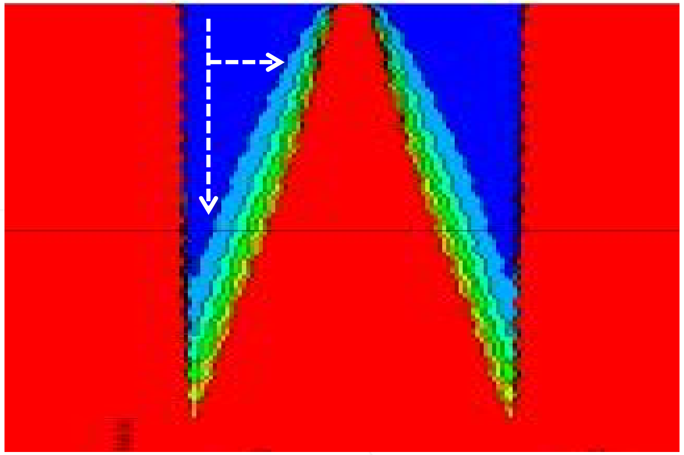


Mismatch due to lateral development



x – z Absorbed Energy

Development Front over time

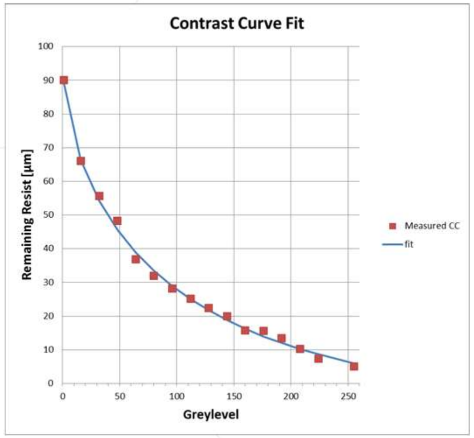


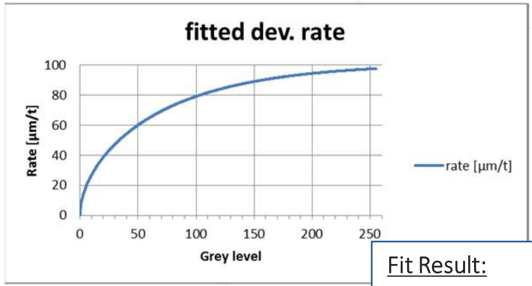
Lateral Development Correction

- 1^{st} Step: fit a rate model to the measured contrast curve (CC)
  - The CC values are simulated by integrating the path from resist top to bottom ending with the development time completed

$$t_{dev} = \int_0^{depth} \frac{dz}{r(z)}$$

  - The rate model used is a typical Mack 4 model



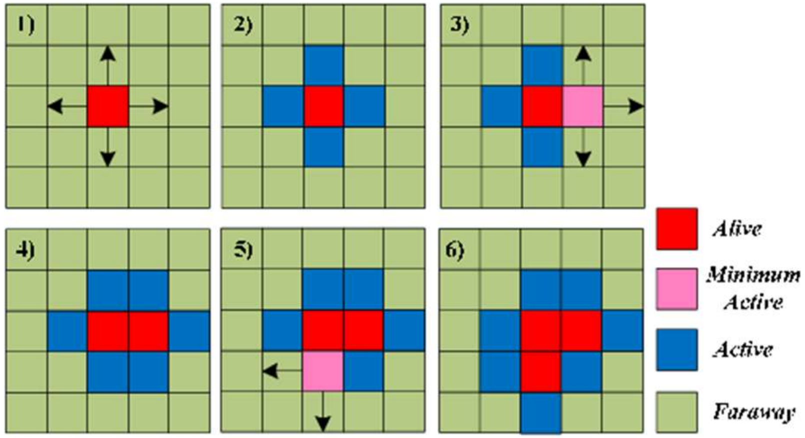


Fit Result:
M_th = -1.00
RateMax = 101.23
RateMin = 0.00
Slope = 0.5145

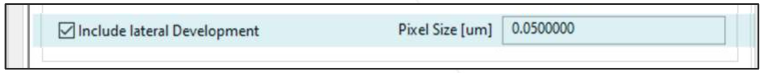
- 2^{nd} step: PEC iteratively refines the applied dose values
  - Applied Dose + local rates R(x,y,z) result in a (computed) depth
  - The difference “computed depth” to “target depth” is an indicator for the required change in dose

Iterative Applied Dose Optimization

- Lateral development is directed. It moves from pixels with higher resist removal to the adjacent pixels with lower rates.
  - Once a pixel is optimized it is not revisited
- Optimizing a pixel:
  - An exposure dose change @ position(x,y) causes a propagation rate(z) change.
  - Iteration finishes when the pixel height is on target
    - Lateral propagation from already visited neighbors is considered
- The performance of the algorithm is strongly pixel size dependent!



Schematic representation of a fast marching method



☑ Include lateral Development

Pixel Size [um] 0.0500000

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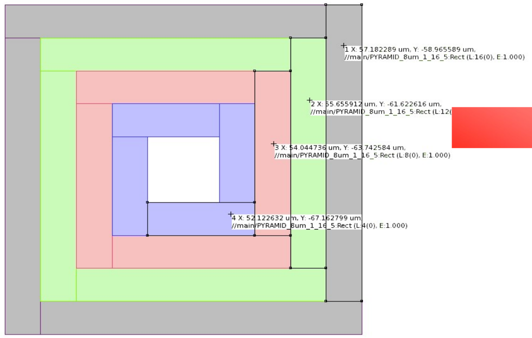
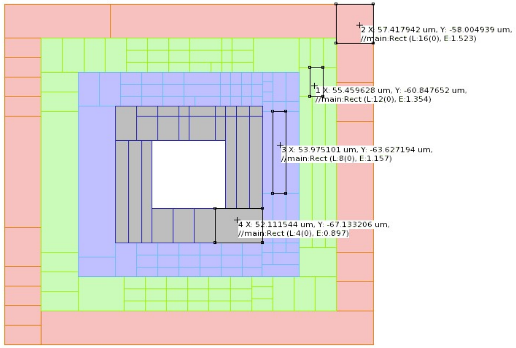
E-Beam Example

Cross-section Target

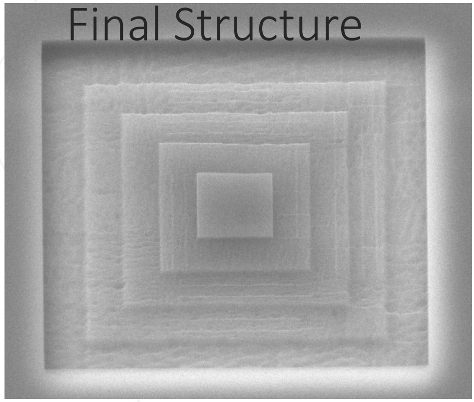
CAD Drawing,
Layer = Height

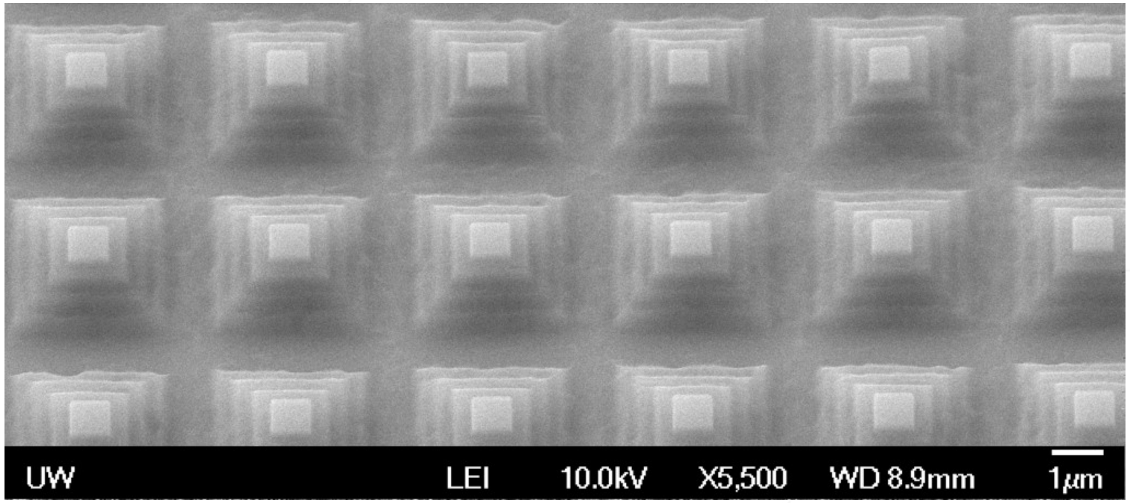


3D PEC Exposure Doses



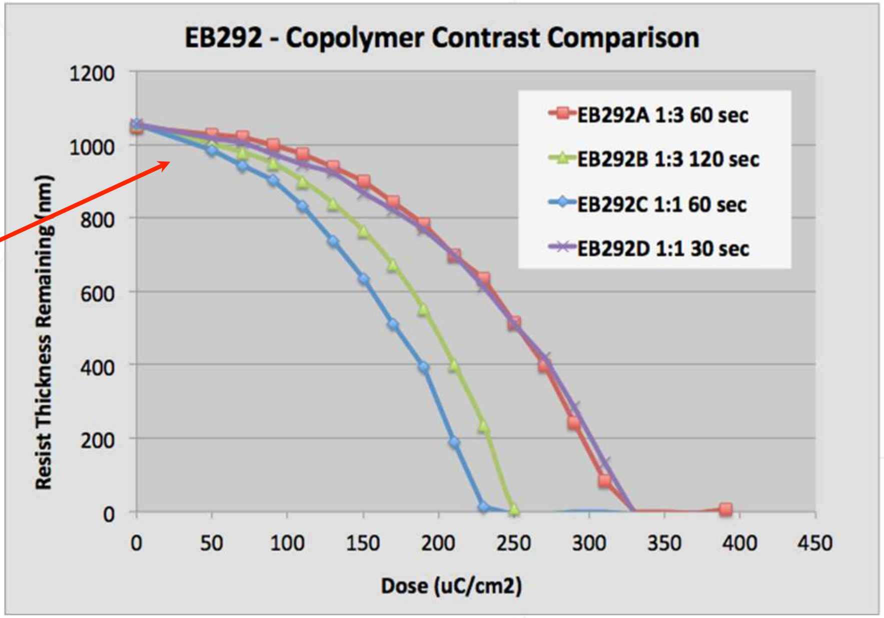
Final Structure





Challenge: Resist Contrast

- Contrast depends on Resist Material & Process
    - Need to choose carefully
    - Must be experimentally measured

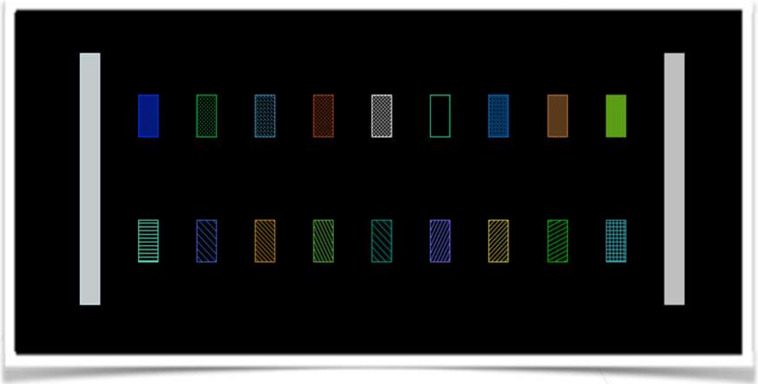


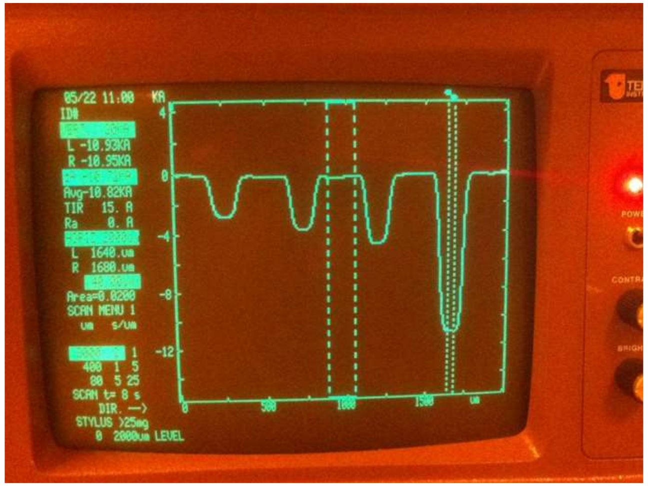
- Contrast Tradeoff
    - Typically desired: lower contrast
        - Height less sensitive to dose fluctuations
    - But, lowest dose is limited by hardware
        - Don’t want too much sensitivity or you can’t achieve shallow depths!

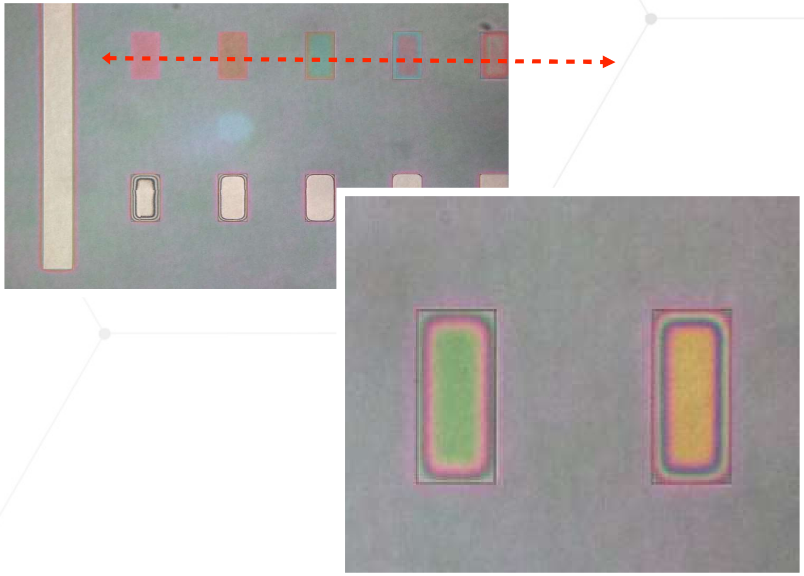
- Lower-contrast resist ⇔ strong lateral development, obscuring the dose assignments

Measuring Resist Contrast Curve

- Expose pattern of shapes with varying dose
  - Width > 3 × Beta (want flat region)
  - Separated, so the shapes do not interact
  - Size easy to measure with profilometer, spectrophotometer ellipsometer, AFM
  - This example, for 100 kV on Si, uses 150 um x 300 um rectangles



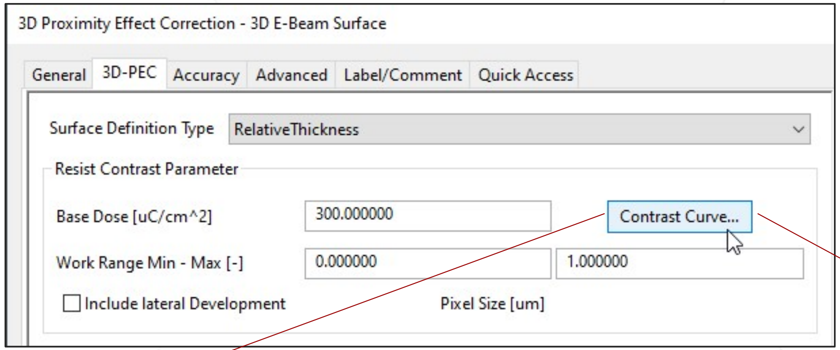




GenISys
Advancing the Standard

Contrast Curve into BEAMER’s 3D-PEC

- The measured contrast curve is imported into BEAMER’s 3D-PEC module
- Sampling of the Contrast curve needs to capture the start and tail with high accuracy if these depths are important



3D Proximity Effect Correction - 3D E-Beam Surface

Surface Definition Type: RelativeThickness

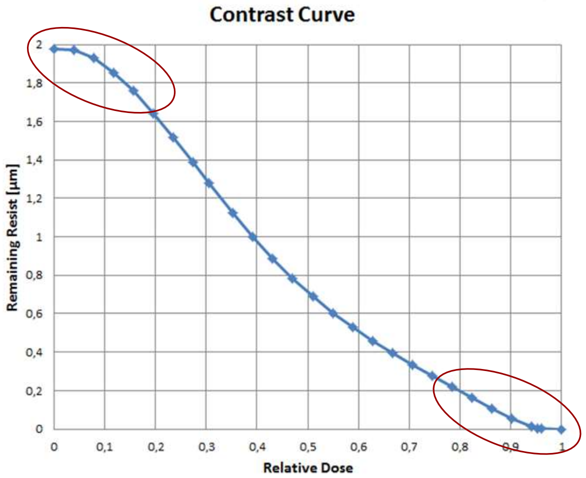
Resist Contrast Parameter

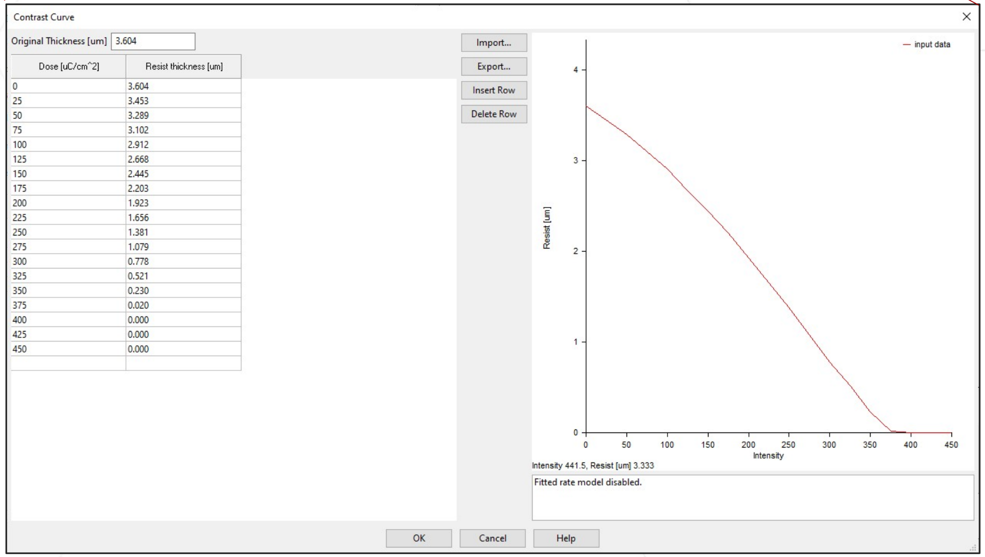
Base Dose [uC/cm^2]: 300.000000

Work Range Min - Max [-]: 0.000000 1.000000

☐ Include lateral Development

Pixel Size [um]





Contrast Curve

Original Thickness [um]: 3.604

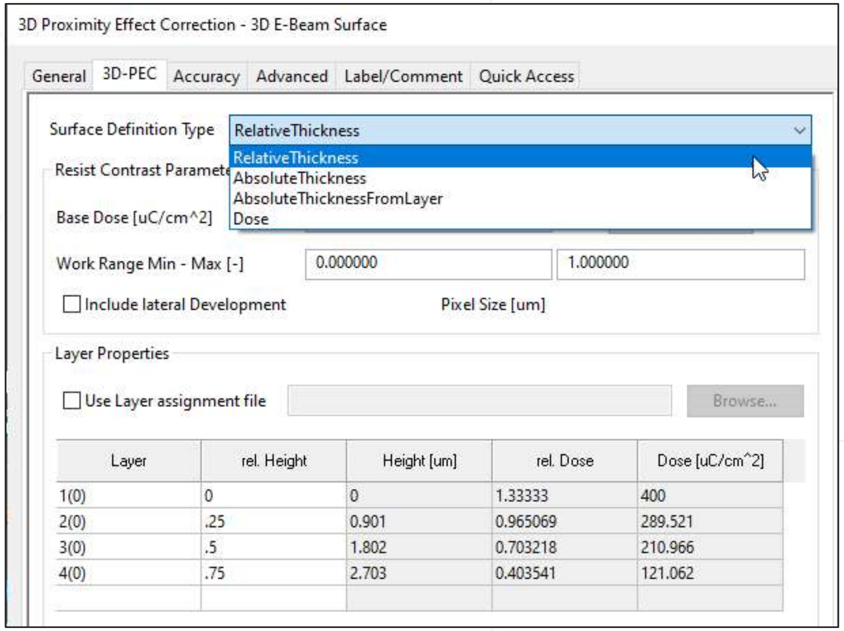
Dose [uC/cm^2]	Resist thickness [um]
0	3.604
25	3.453
50	3.289
75	3.102
100	2.912
125	2.668
150	2.445
175	2.203
200	1.923
225	1.656
250	1.381
275	1.079
300	0.778
325	0.521
350	0.230
375	0.020
400	0.000
425	0.000
450	0.000

Intensity 441.5, Resist [um] 3.333

Fitted rate model disabled.

Specifying Target Height

- The target height for each layer can be specified as:
  - Relative, to the resist thickness
  - Absolute thickness
  - Absolute from the layer name (eg. STL Import)
  - Dose direct assignment



Surface Definition Type: RelativeThickness

Work Range Min - Max [-]: 0.000000 1.000000

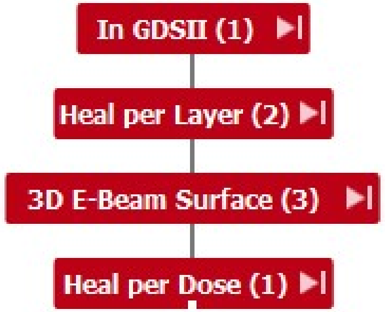
☐ Include lateral Development

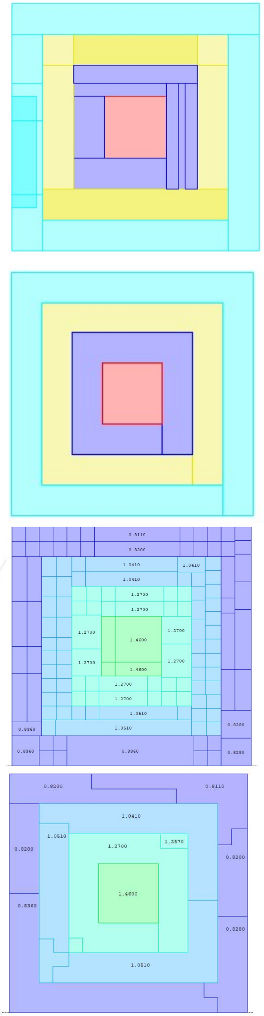
☐ Use Layer assignment file

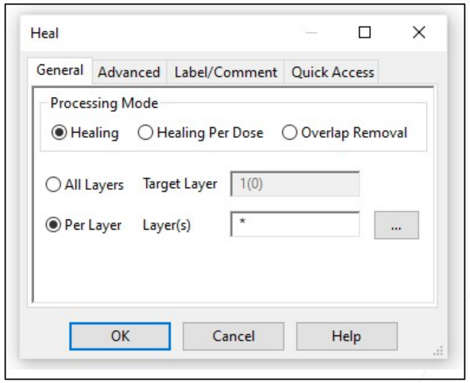
Layer	rel. Height	Height [um]	rel. Dose	Dose [uC/cm^2]
1(0)	0	0	1.33333	400
2(0)	.25	0.901	0.965069	289.521
3(0)	.5	1.802	0.703218	210.966
4(0)	.75	2.703	0.403541	121.062

Some Design & Usage Guidelines

- Each target height is designed on a different CAD layer
- Do not want overlaps in the design – this creates an ambiguous height target
- Heal per Layer before the 3D-PEC removes unnecessary shape boundaries in the design
- Heal per Dose after the 3D-PEC removes unnecessary fractures







Heal

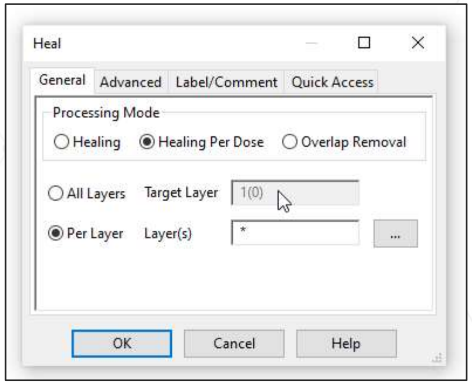
General | Advanced | Label/Comment | Quick Access

Processing Mode

● Healing ○ Healing Per Dose ○ Overlap Removal

○ All Layers Target Layer 1(0)

● Per Layer Layer(s) *



Heal

General | Advanced | Label/Comment | Quick Access

Processing Mode

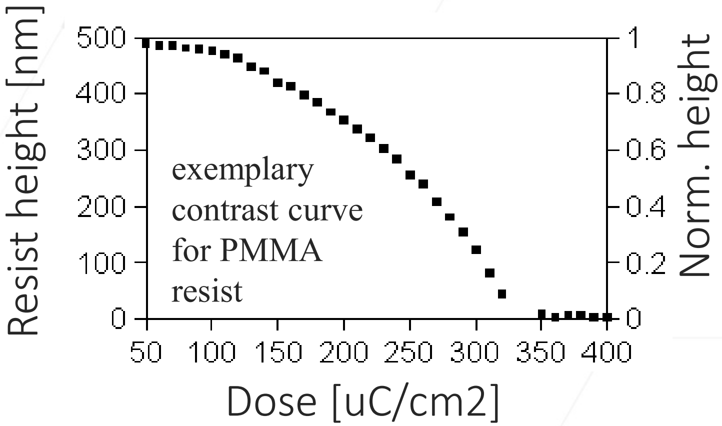
○ Healing ● Healing Per Dose ○ Overlap Removal

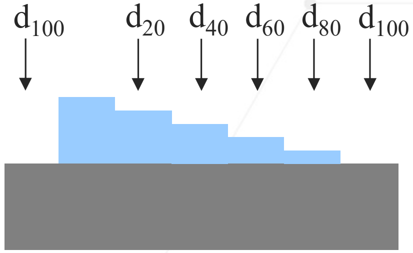
○ All Layers Target Layer 1(0)

● Per Layer Layer(s) *

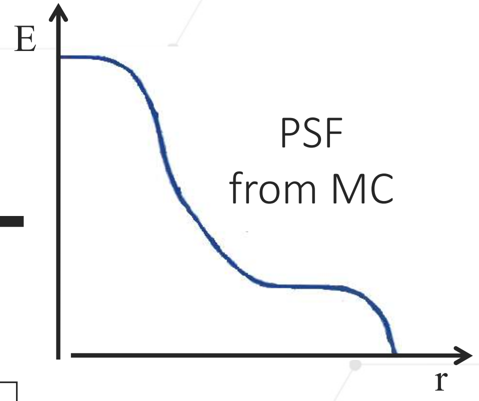
E-Beam Grayscale Correction

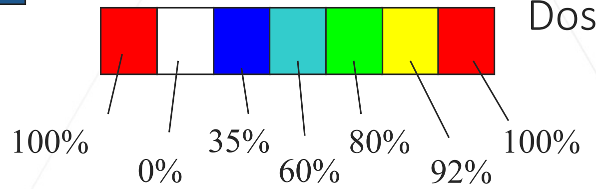
Process chain for multilevel resist pattern (grayscale electron-beam lithography)



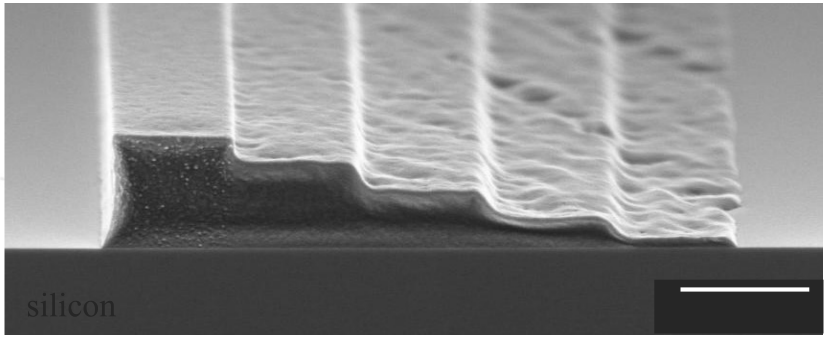


Resist pattern (cross section)



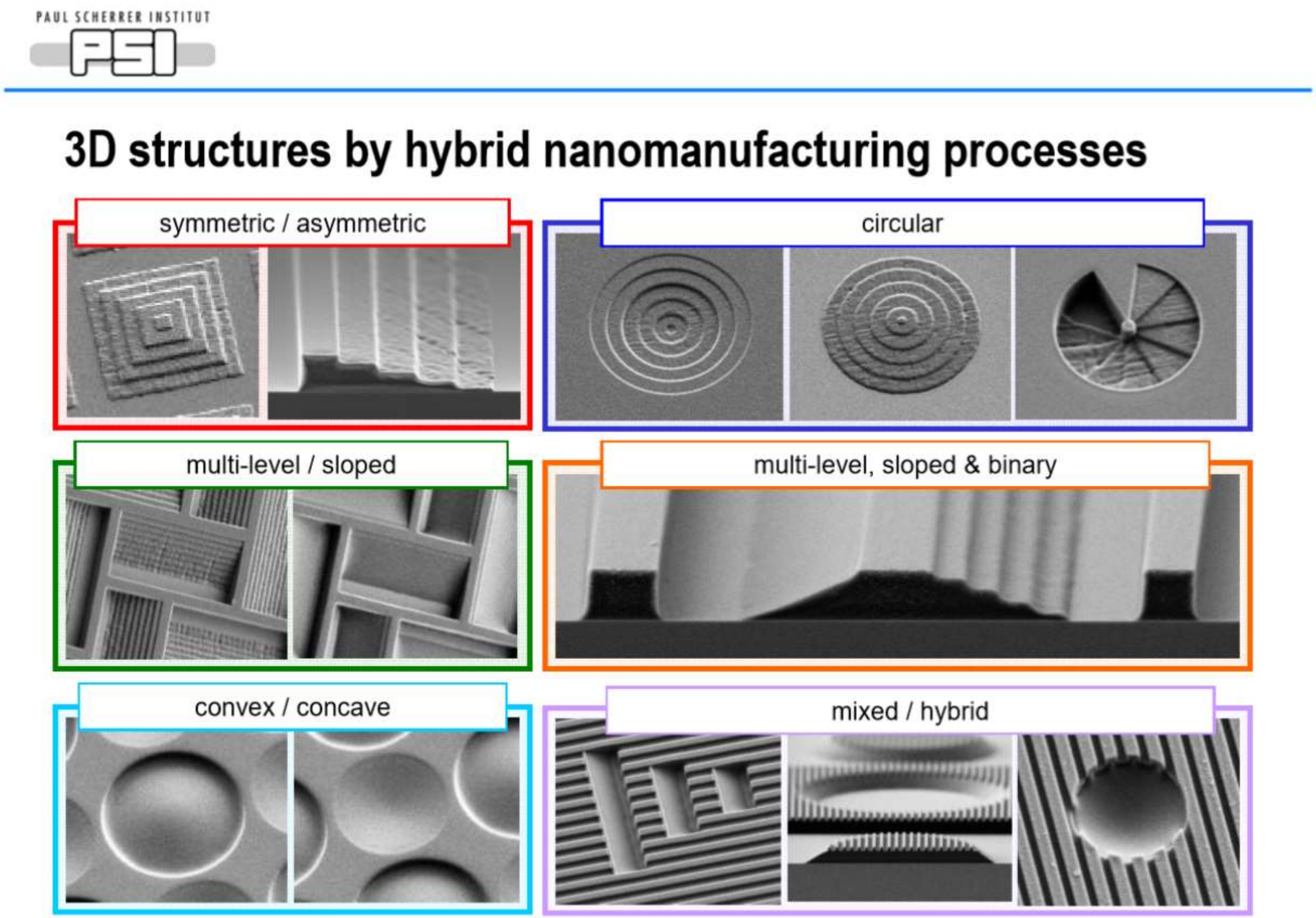


Dose distribution (top view)



1050 nm high PMMA resist after development

Some more 3D samples of E-BEAM



PAUL SCHERRER INSTITUT PSI

3D structures by hybrid nanomanufacturing processes

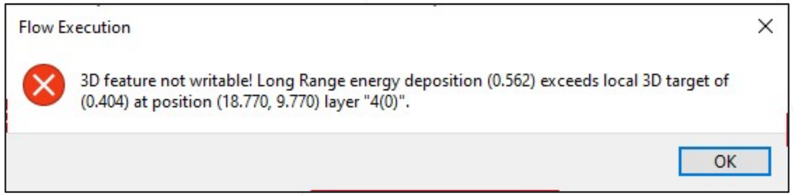
Courtesy of PSI, Switzerland

Outline

- Part 5 Summary: Shape PEC – ODUS Contrast Enhancement
- Introduction to 3D Lithography
- 3D-PEC for E-Beam Lithography
  - Dose Correction and Lateral Development
  - Implementation Details
  - Additional Effects and Corrections in E-Beam 3D-PEC
- 3D-PEC for Laser Lithography
- Summary

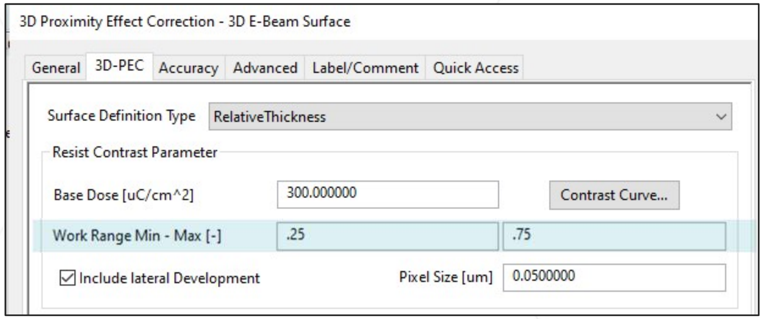
Work Range

- The extreme shallow and deep portions of the contrast curve have complex behavior
- The extremely low doses required for the very shallow depths can exceed the hardware capabilities (maximum exposure clock rate) of e-beam tools
- Too much scattered energy can make some designs impossible



3D feature not writable! Long Range energy deposition (0.562) exceeds local 3D target of (0.404) at position (18.770, 9.770) layer "4(0)".

- Work Range shifts the relative target height assignments to the specified range, avoiding all of these issues
- You may need to use a thicker total resist thickness to achieve the same total height modulation



Surface Definition Type: RelativeThickness

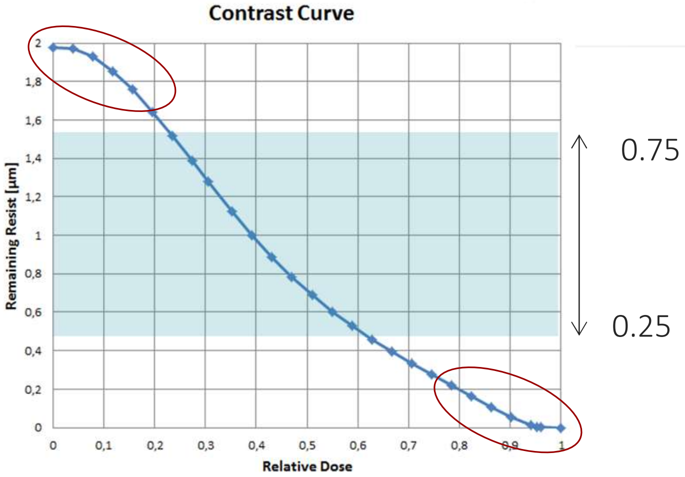
Resist Contrast Parameter

Base Dose [uC/cm^2]: 300.000000

Work Range Min - Max [-]: .25 .75

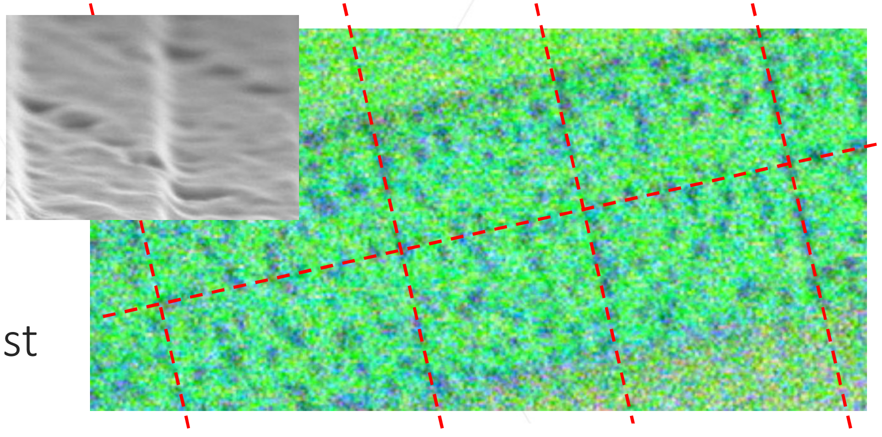
☑ Include lateral Development

Pixel Size [um]: 0.0500000

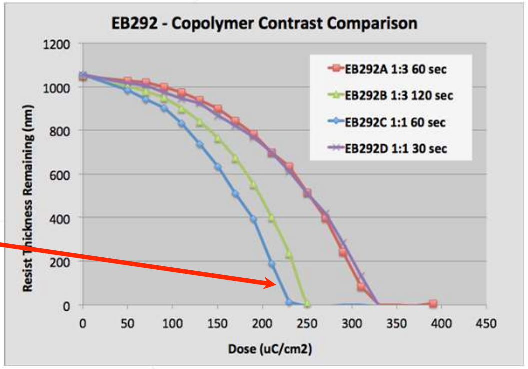


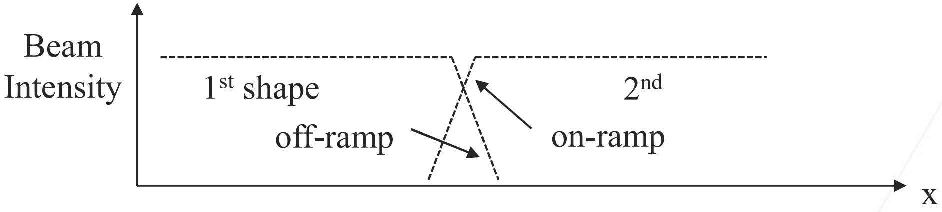
Exposure Issues

- Resist surfaces sometimes show roughness, holes, or bumps, often at regular spacing, indicating dosing issues at shape or sub-field borders
- Can be caused by tool calibration or timing issues
  - Optimal calibration for binary lithography may not be best for 3D. Tools may be calibrated for slight sub-field overlaps, to avoid unwanted gaps at boundaries.
  - Scanning/Blanking timing and synchronization may have tiny errors.
  - The slight dose changes are invisible in binary lithography, but give visible imperfections in 3D
  - The effect is more pronounced at higher doses, as the slope is steeper at higher doses



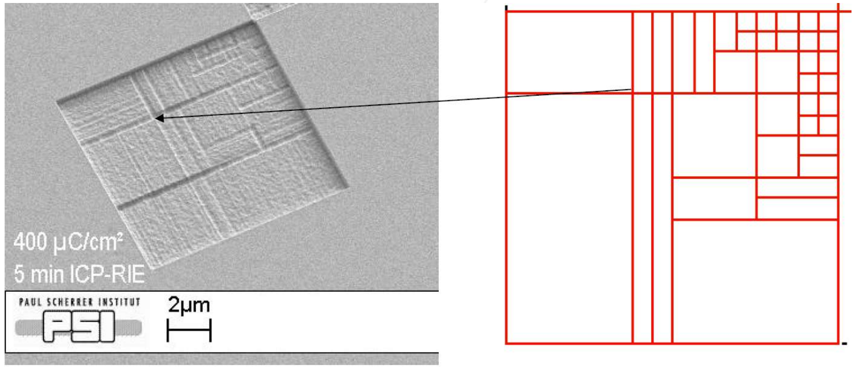
Courtesy: TU Eindhoven



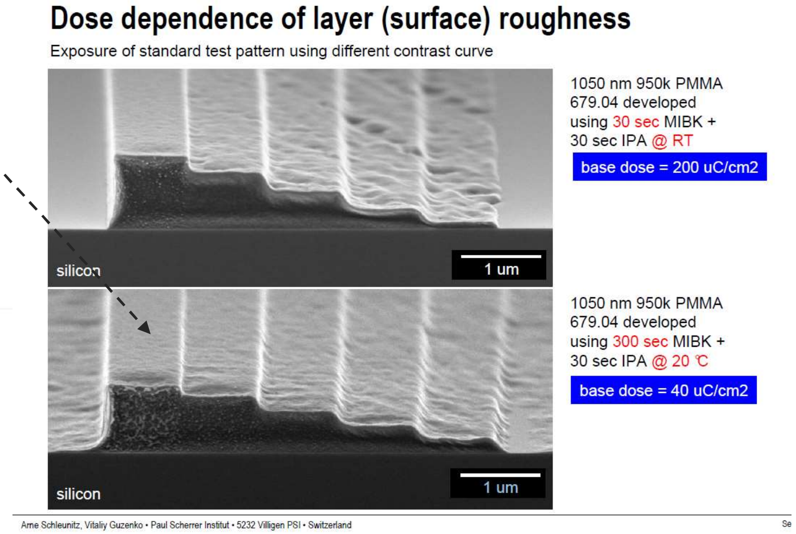


Mitigation by Exposure Strategy

- Resist Process
  - Resist contrast impacts height sensitivity
- Amplifier Gain
  - Allow small gaps between shots
- Larger Spots
  - Blurs the Dose Non-Uniformities
- Multi-Pass, particularly with sub-field shift
  - Averages Dose Non-Uniformities
- Dose-sensitive Multi-Pass
  - Higher doses (lower heights in positive resists) are exposed multiple times; Lower doses exposed fewer times.
  - Improves throughput, by using Multipass with higher current while staying within machine maximum frequency
- Multi-Pass with Overlap Mode
  - Multiplex exposure by intentional overlaps



PSI Example, showing clear effects at fracture borders



Dose dependence of layer (surface) roughness

Exposure of standard test pattern using different contrast curve

1050 nm 950k PMMA
679.04 developed
using 30 sec MIBK +
30 sec IPA @ RT

base dose = 200 uC/cm2

1050 nm 950k PMMA
679.04 developed
using 300 sec MIBK +
30 sec IPA @ 20 ℃

base dose = 40 uC/cm2

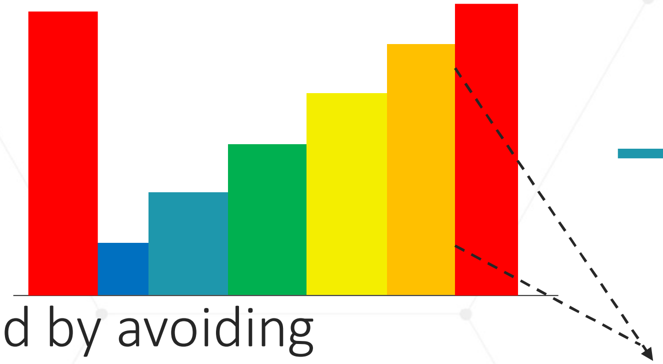
Arne Schleunitz, Vitaliy Guzenko • Paul Scherrer Institut • 5232 Villigen PSI • Switzerland

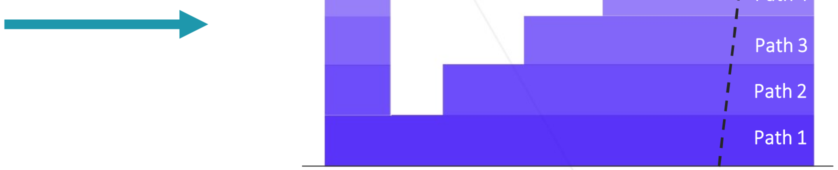
Se

Multi-Pass with Overlap Mode

- Stacked shapes, with each adding incremental dose to the lower layer doses

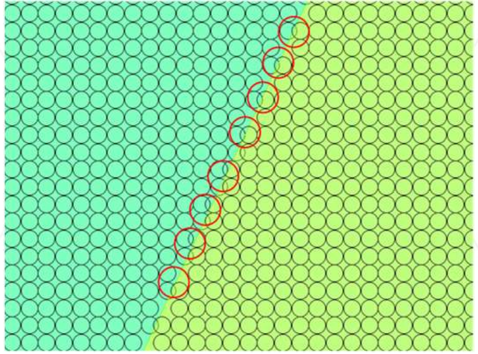
Desired Dose Profile




Overlap Mode Exposure Strategy

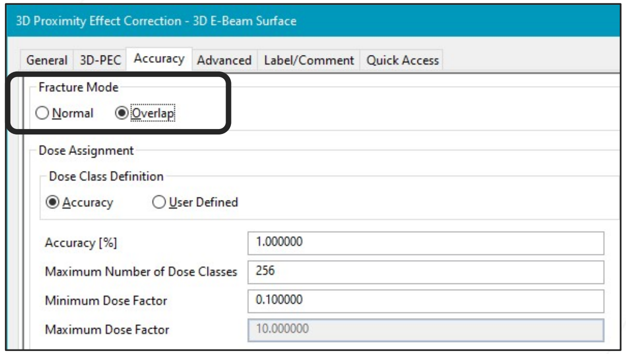
- Shape boundaries improved by avoiding gaps and overlapping shots at edges

„Hard“ dose boundary always there, even with multi-pass



Dose boundary only in top exposure

- New in BEAMER v6.1



3D Proximity Effect Correction - 3D E-Beam Surface

Fracture Mode

○ Normal ● Overlap

Dose Assignment

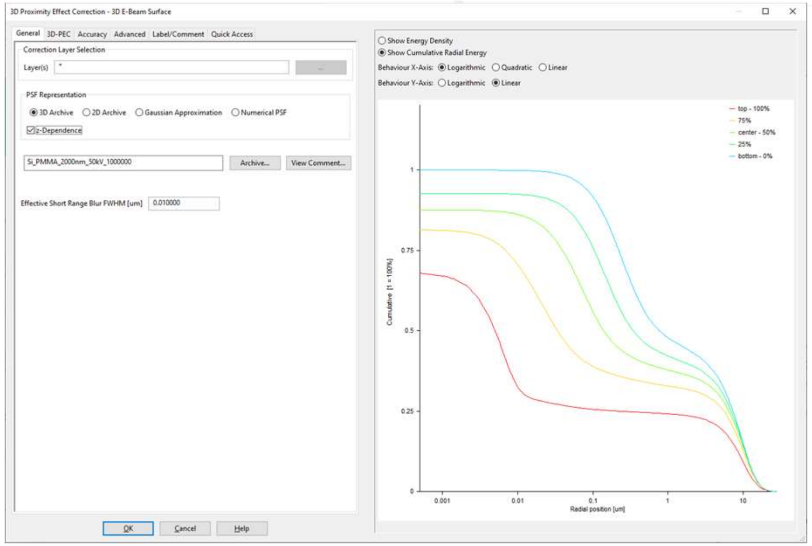
Dose Class Definition

● Accuracy ○ User Defined

Accuracy [%]	1.000000
Maximum Number of Dose Classes	256
Minimum Dose Factor	0.100000
Maximum Dose Factor	10.000000

New Improvement: 3-D PSF

- So far, we have used a 2-D PSF for PEC
- But absorbed energy will vary with Z position within the resist layer, especially in thicker layers
- A new extension to 3D-PEC is the ability use a 3D-PSF


3D Proximity Effect Correction - 3D E-Beam Surface

General | 3D-PEC | Accuracy | Advanced | Label/Comment | Quick Access

Correction Layer Selection

Layer(s): *

PSF Representation

● 3D Archive ○ 2D Archive ○ Gaussian Approximation ○ Numerical PSF

☑ z-Dependence

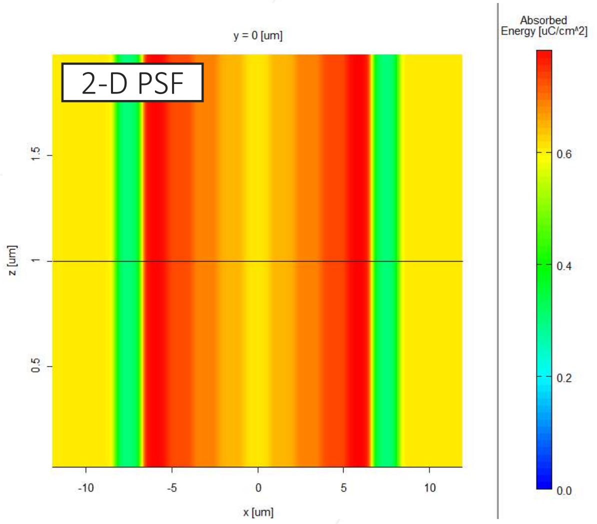
Si_PMMA_2000nm_50kV_1000000

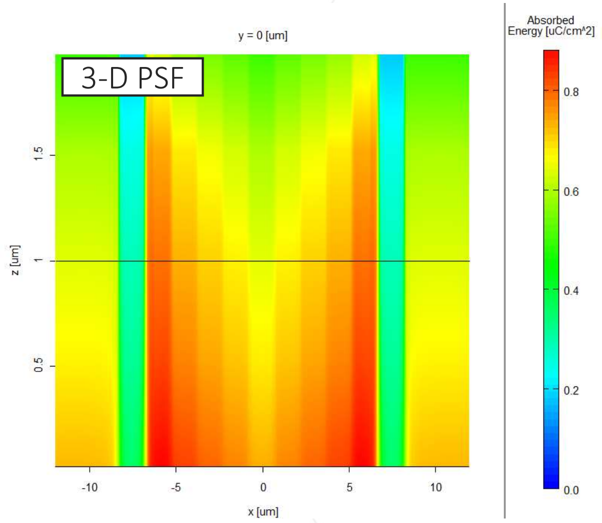
Effective Short Range Blur FWHM [um]: 0.010000

○ Show Energy Density
● Show Cumulative Radial Energy

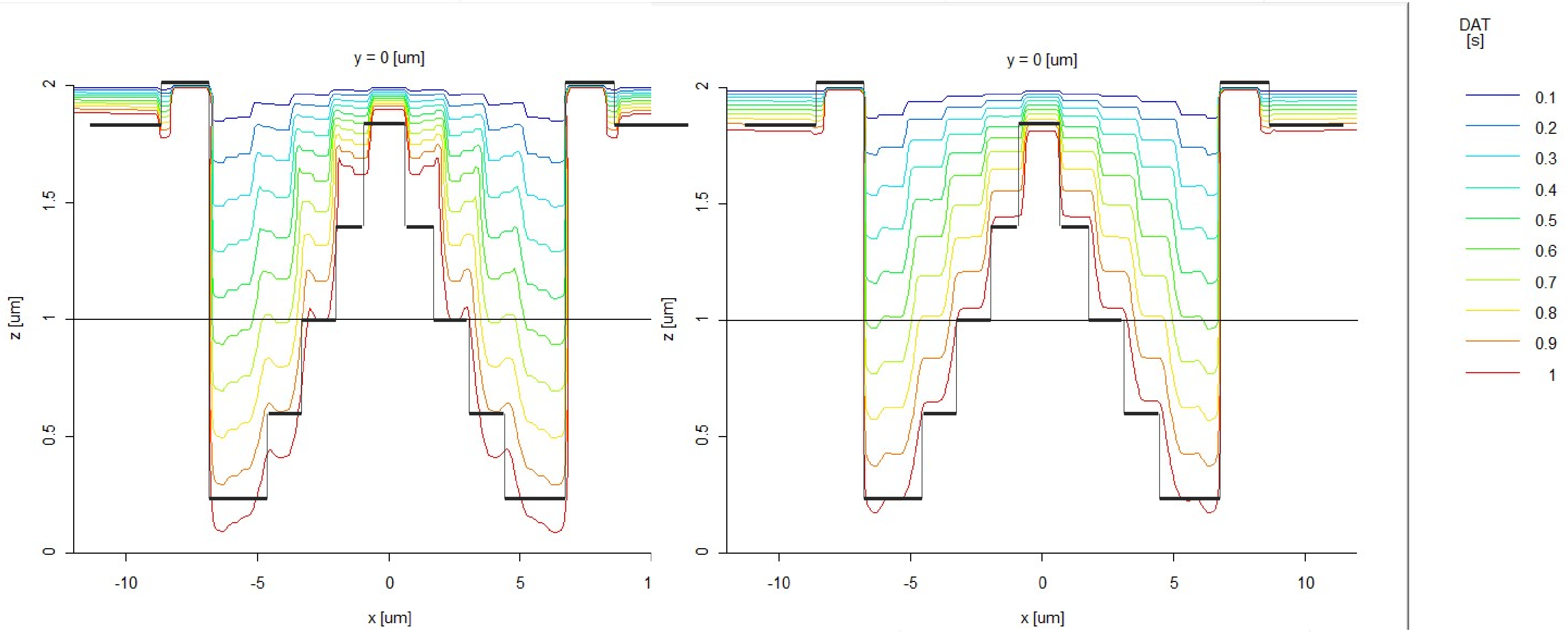
Behaviour X-Axis: ● Logarithmic ○ Quadratic ○ Linear

Behaviour Y-Axis: ○ Logarithmic ● Linear





Impact of 3D PSF, Development Profiles

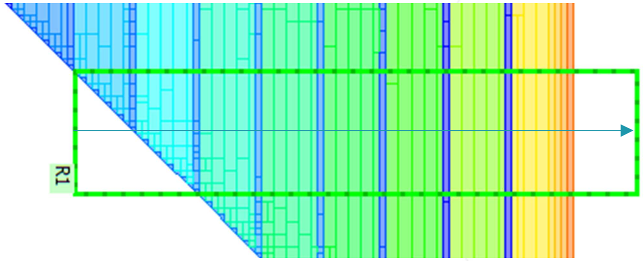


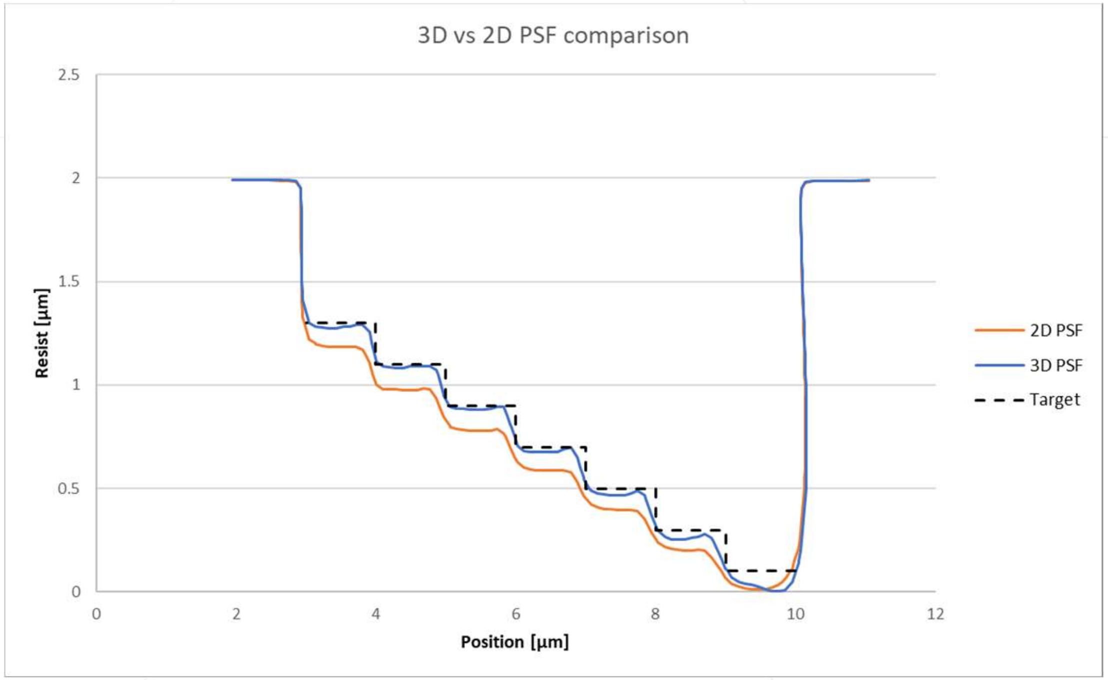
Using 2-D PSF (center)

Using full 3D PSF

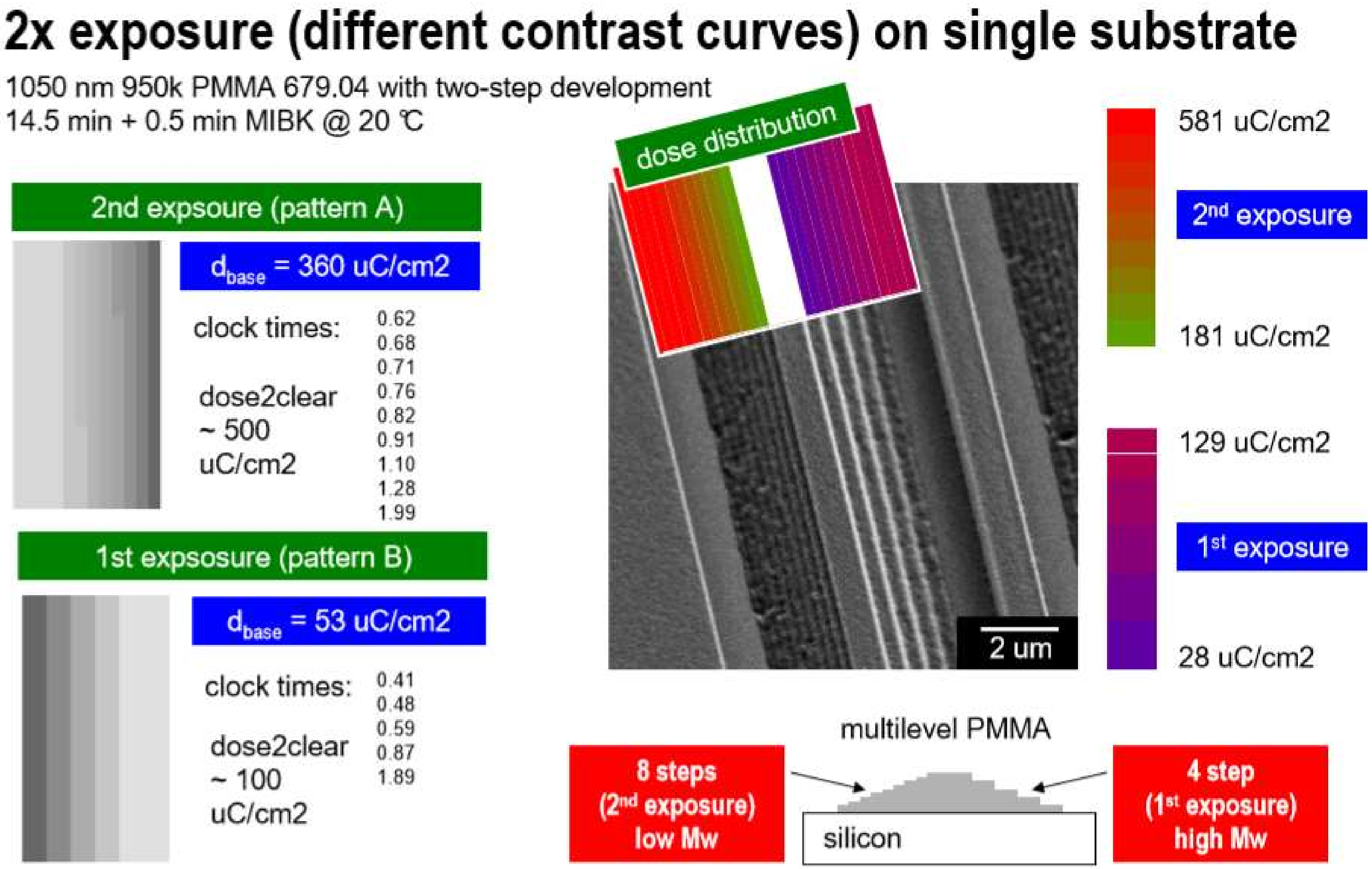
Impact of 3D PSF: Height Targets

- This new feature improves the accuracy of the 3D-PEC, yielding resist thicknesses closer to the target
- Higher accuracy, but more computationally intensive
- Available in BEAMER v6.1





Advanced Example: Multiple Process



2x exposure (different contrast curves) on single substrate

1050 nm 950k PMMA 679.04 with two-step development
14.5 min + 0.5 min MIBK @ 20 ℃

2nd expsoure (pattern A)

d_{base} = 360 uC/cm2

clock times:
0.62
0.68
0.71
0.76
0.82
0.91
1.10
1.28
1.99

dose2clear
~ 500
uC/cm2

1st expsosure (pattern B)

d_{base} = 53 uC/cm2

clock times:
0.41
0.48
0.59
0.87
1.89

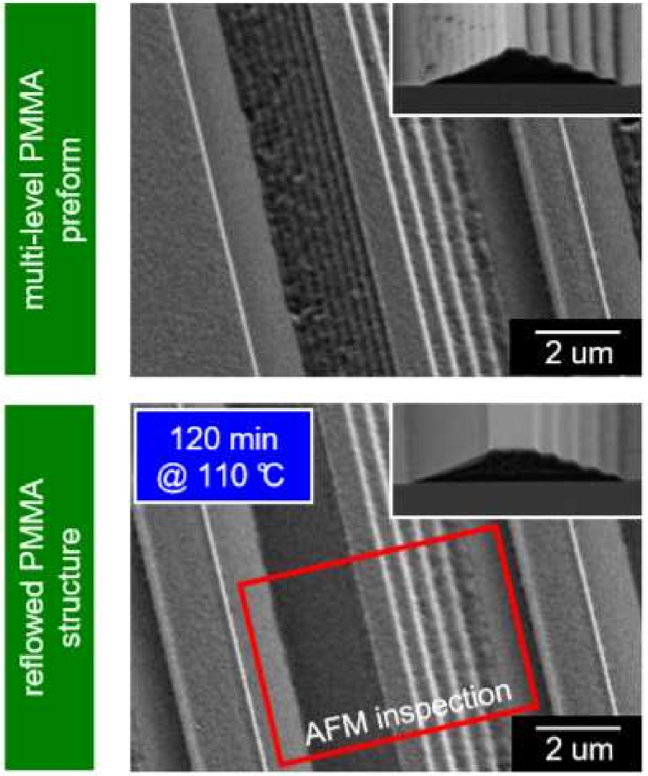
dose2clear
~ 100
uC/cm2

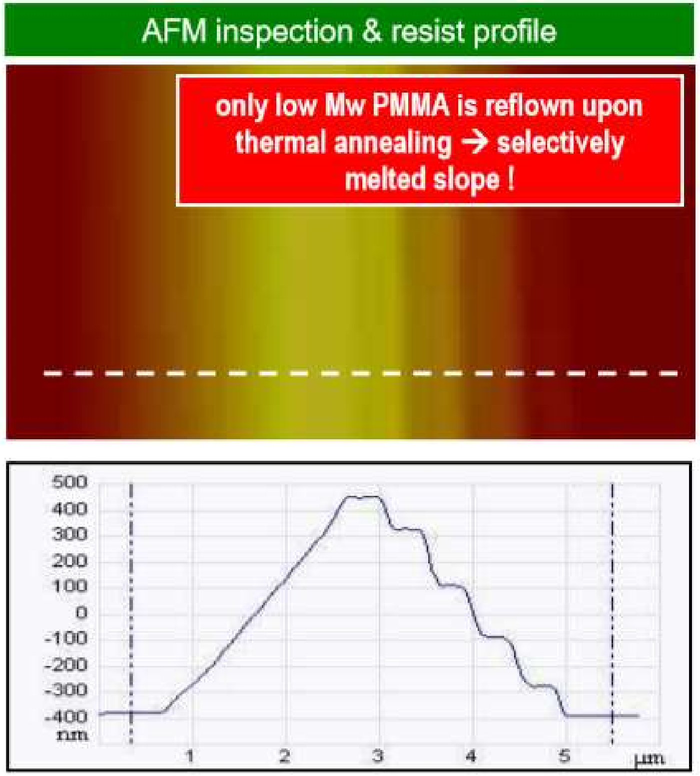
Courtesy of
PSI, Switzerland

Advanced Example: Resist Reflow

Multi-level and continuous resist profiles

Thermal annealing applied to EBL patterned multi-level PMMA



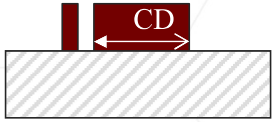


only low Mw PMMA is reflown upon thermal annealing → selectively melted slope !

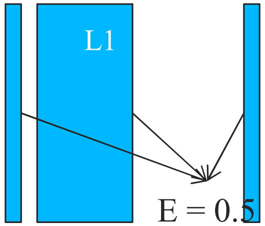
Courtesy of
PSI, Switzerland

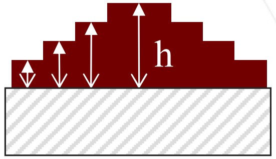
E-Beam 3D Surface PEC Summary

- Computation aims to match the height of the resist surface to the defined target.
  - The height of a resist layer can be controlled by adjusting the dose
- Basic 3D Surface PEC takes into account:
  - Blur and Backscattered Energy in the resist
  - Lateral Development
- Additional options for mitigation other effects:
  - Multipass, Including dose-selective
  - Stacked Overlap Mode (new)
  - 3D-PSF for improved accuracy in thicker layers (new)

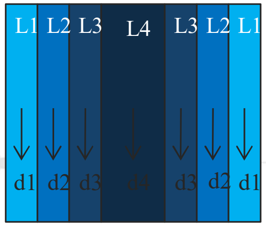


Correction Target





Correction Target



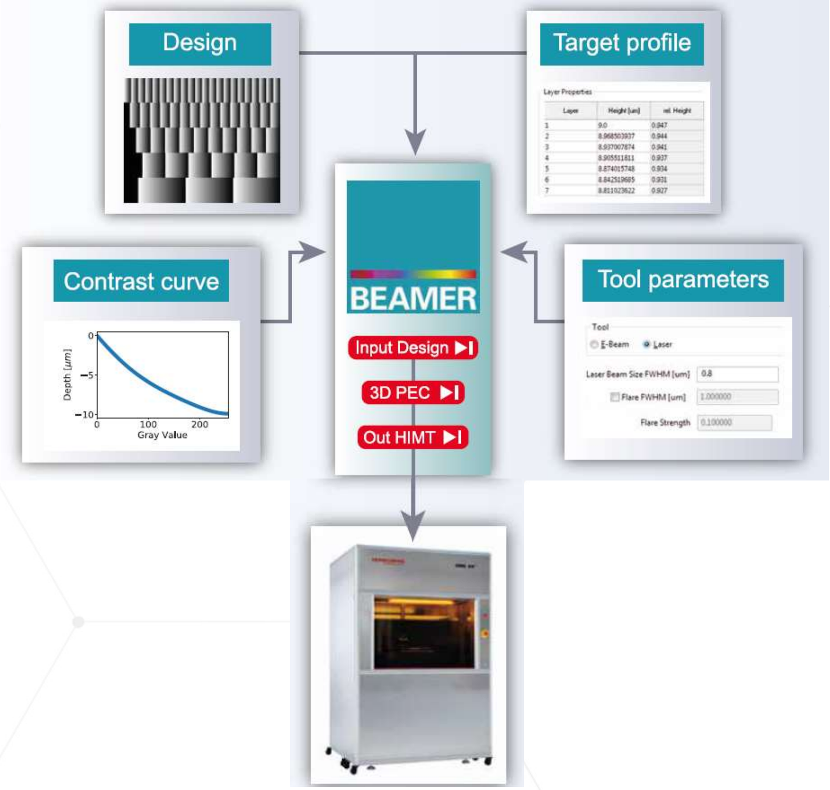
Outline

- Part 5 Summary: Shape PEC – ODUS Contrast Enhancement
- Introduction to 3D Lithography
- 3D-PEC for E-Beam Lithography
- 3D-PEC for Laser Lithography
- Summary

Laser Grayscale Correction

- 3D Surface PEC can also be applied to optical exposure by laser

- Similar basics, additional effects
    - More complex resist response
    - Absorption, Bleaching



Layer Properties

Layer	Height [um]	rel. Height
1	9.0	0.947
2	8.968503937	0.944
3	8.937007874	0.941
4	8.905511811	0.937
5	8.874015748	0.934
6	8.842519685	0.931
7	8.811023622	0.927

Tool

○ E-Beam ● Laser

Laser Beam Size FWHM [um] 0.8

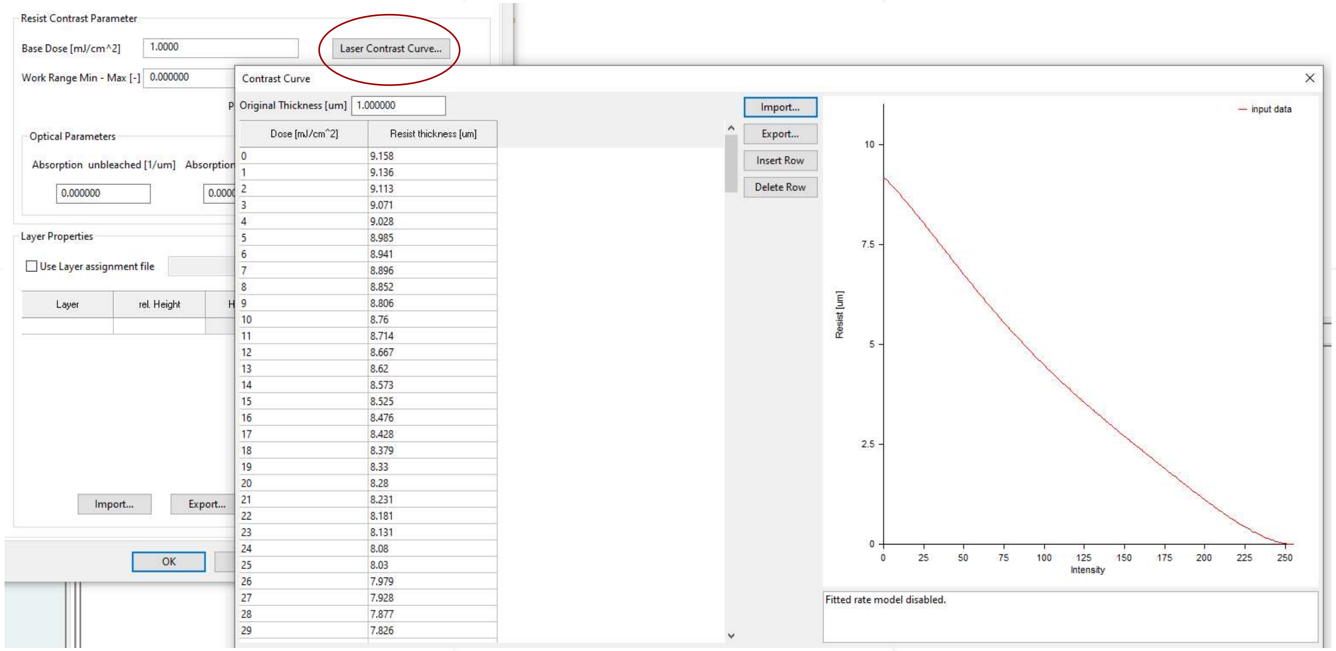
☐ Flare FWHM [um] 1.000000

Flare Strength 0.100000

3D-PEC for Laser

- The basis of the 3D-PEC is still Development Rate, from the Contrast Curve

- Measured by experiment
- Entered into BEAMER



Resist Contrast Parameter

Base Dose [mJ/cm^2] 1.0000

Work Range Min - Max [-] 0.000000

Optical Parameters

Absorption unbleached [1/um] 0.000000

Layer Properties

☐ Use Layer assignment file

Layer	rel. Height

Contrast Curve

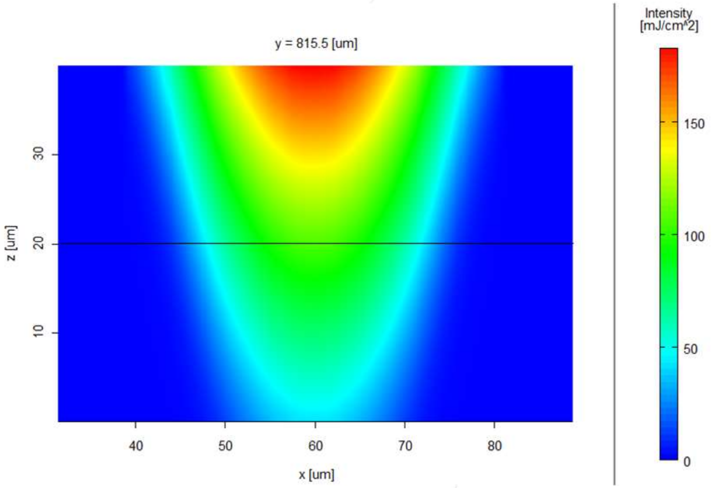
Original Thickness [um] 1.000000

	Dose [mJ/cm^2]	Resist thickness [um]
0		9.158
1		9.136
2		9.113
3		9.071
4		9.028
5		8.985
6		8.941
7		8.896
8		8.852
9		8.806
10		8.76
11		8.714
12		8.667
13		8.62
14		8.573
15		8.525
16		8.476
17		8.428
18		8.379
19		8.33
20		8.28
21		8.231
22		8.181
23		8.131
24		8.08
25		8.03
26		7.979
27		7.928
28		7.877
29		7.826

Fitted rate model disabled.

Laser 3D Lithography Challenges

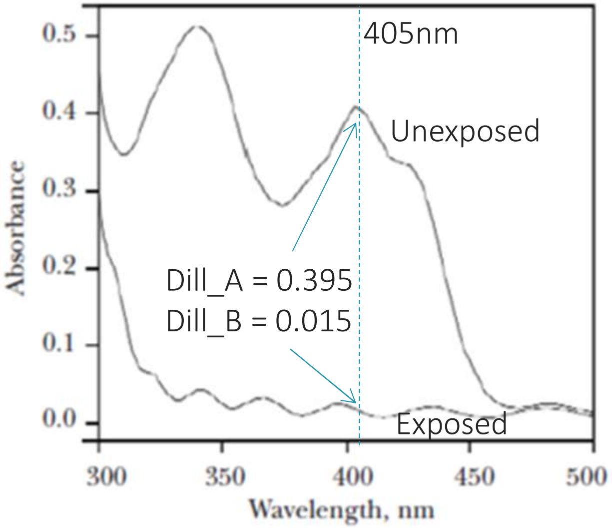
- Energy Absorption
  - Blur
    - Laser Beam Size blurs the energy
  - Energy Variation in Z
    - Absorption, Bleaching, Depth of Focus



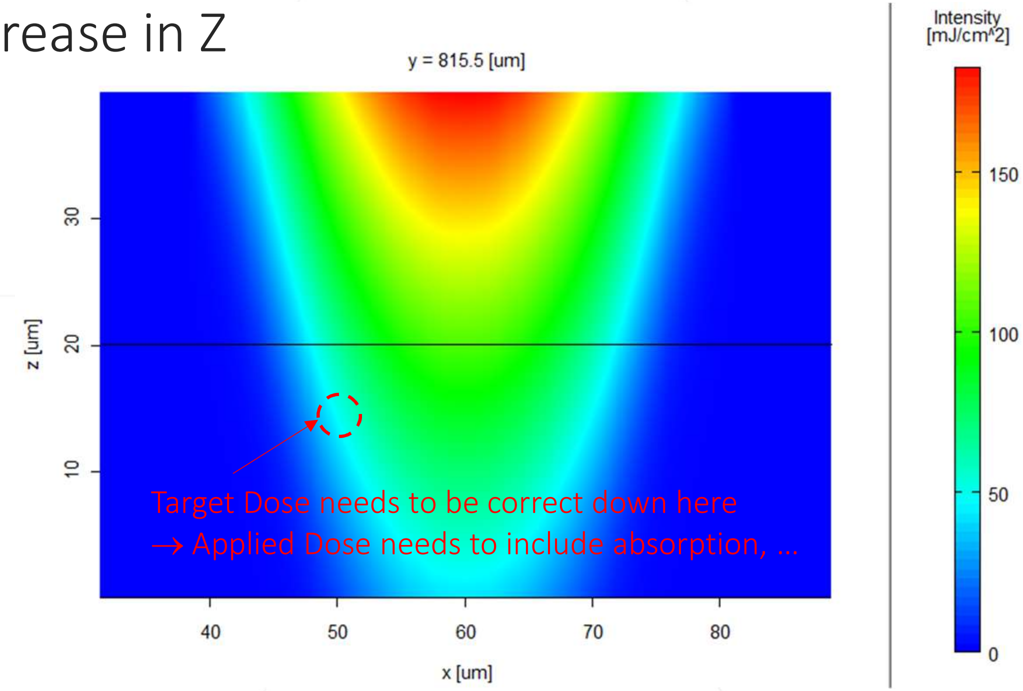
- Development
  - Lateral Development
  - Surface Inhibition
  - Z-dependent Development Rates, especially with thicker resist

Z-dependent Exposure Effects

- Additional resist parameters are needed
  - Absorption and bleaching affect the z-dependent absorbed dose (x,y,z)
  - Intensity and development rate decrease in Z



Absorbance Curves for SPR220 Resist



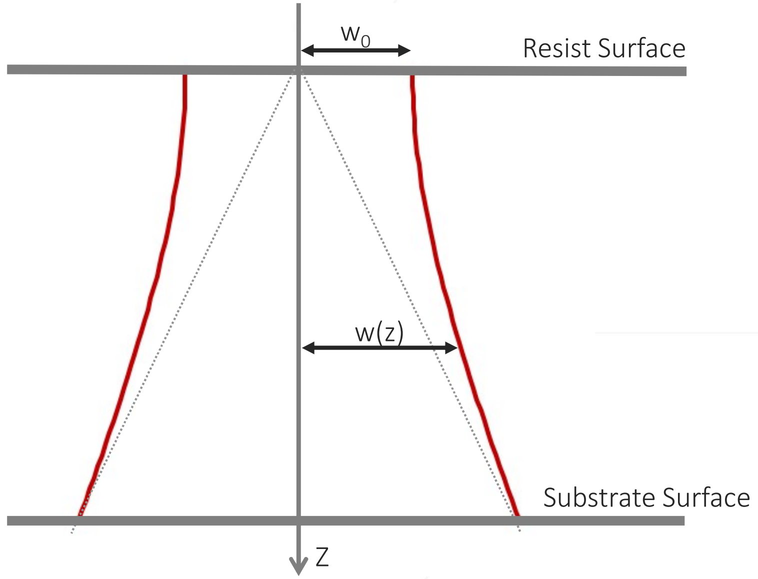
Target Dose needs to be correct down here
→ Applied Dose needs to include absorption, …

Sample dose profile in a 40µm thick resist

Accurate modeling of absorbed energy is essential for 3D PEC

Beam Divergence

- Spot size varies through the resist

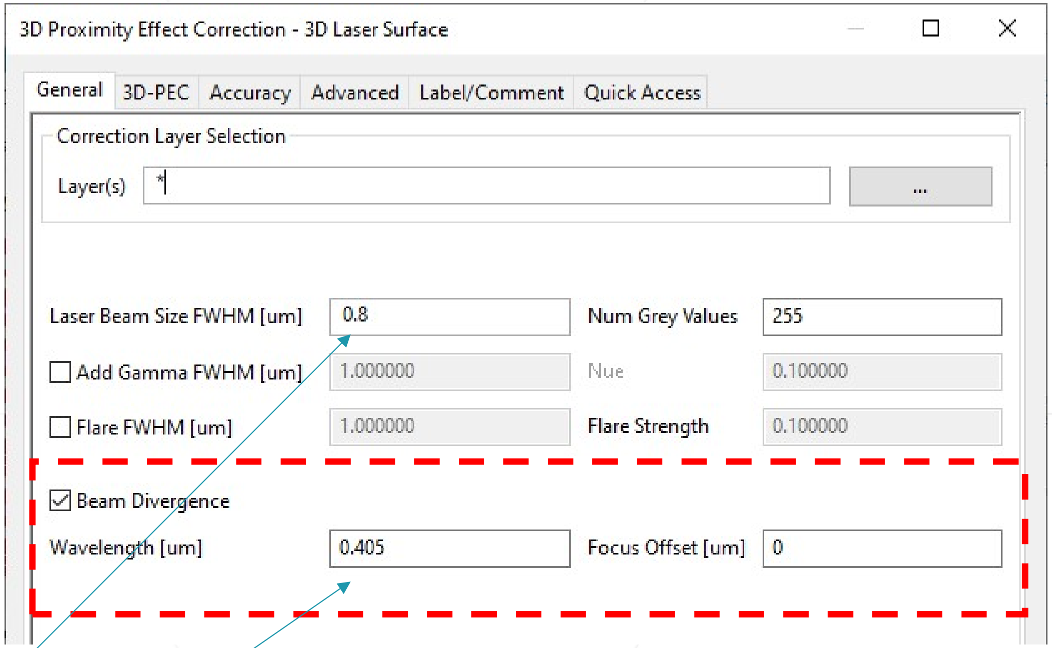


$$z_R = n w_0 / \mathrm{NA}.$$

$$w_o = \frac{FWHM}{2\sqrt{\ln 2}}$$

$$w(z) = w_0 \sqrt{1 + \left(\frac{z}{z_R}\right)^2},$$

$$\boxed{z_R = \frac{n \cdot \pi \cdot w_0^2}{\lambda_0}}$$



Layer(s): *

Laser Beam Size FWHM [um]: 0.8

Num Grey Values: 255

☐ Add Gamma FWHM [um]: 1.000000

Nue: 0.100000

☐ Flare FWHM [um]: 1.000000

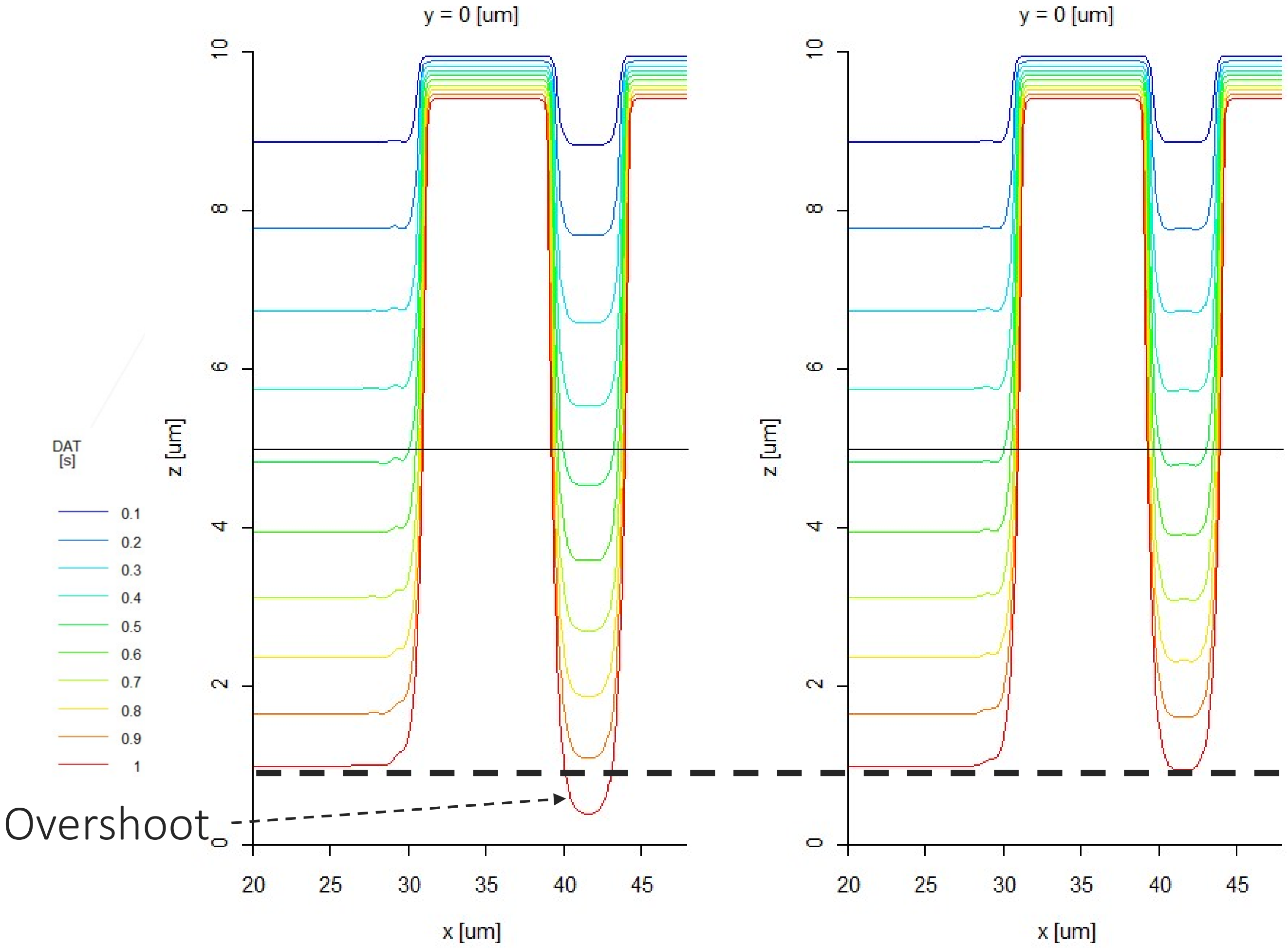
Flare Strength: 0.100000

☑ Beam Divergence

Wavelength [um]: 0.405

Focus Offset [um]: 0

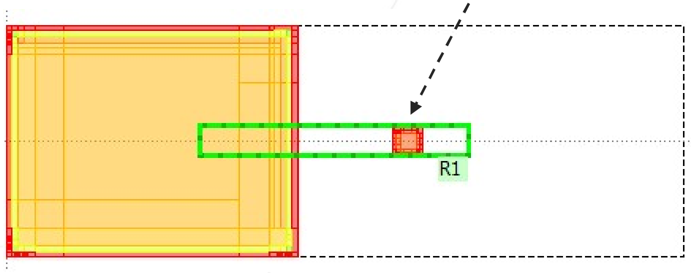
Beam Divergence Impact



Without Beam Divergence

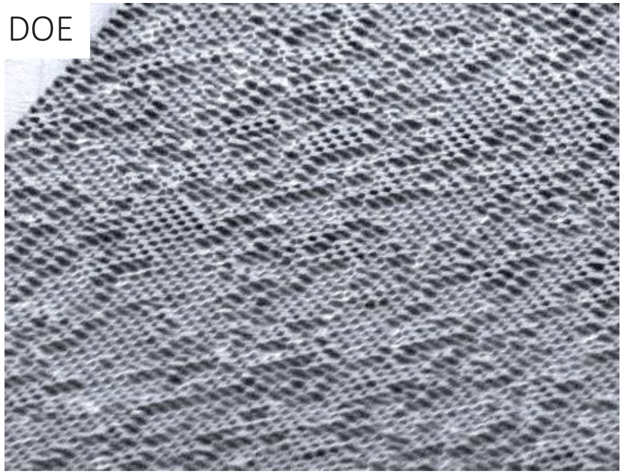
With Beam Divergence

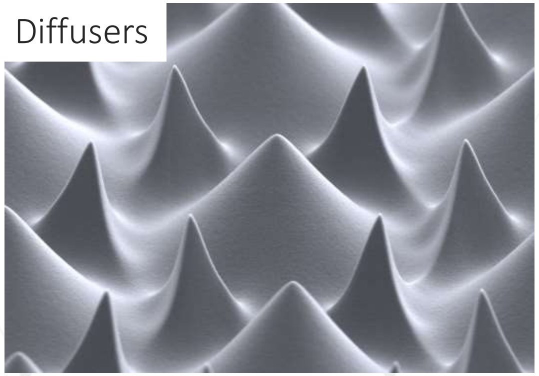
The depth of focus compensation makes a difference for <u>narrow</u> features where dose is blurred to the sides



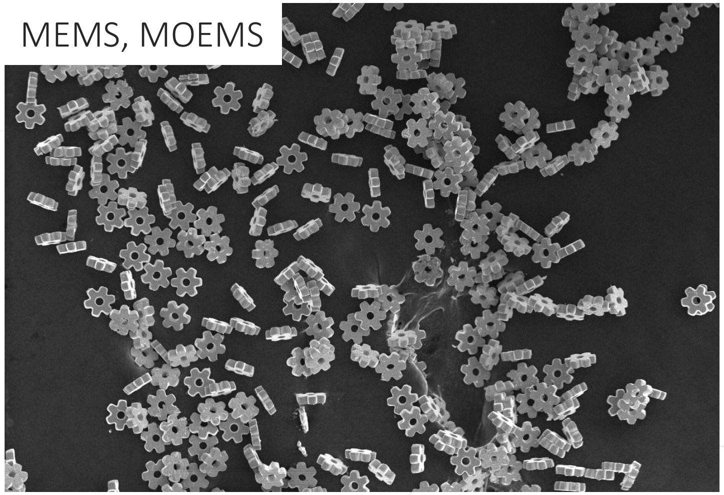
Laser Grayscale Applications

- Many applications require 3-D Lithography

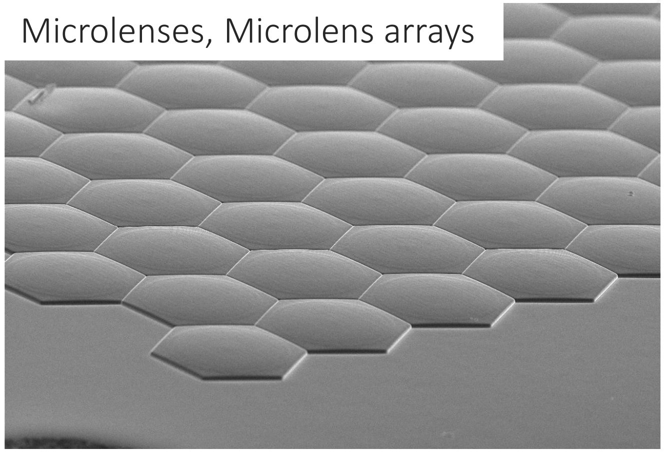

DOE

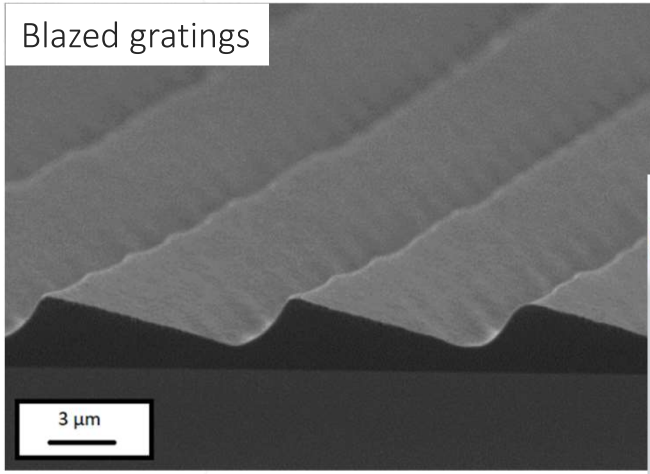

Diffusers

Courtesy of IGI

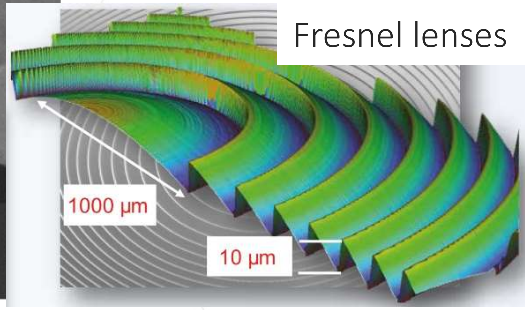

MEMS, MOEMS

Courtesy of Kuraray


Microlenses, Microlens arrays

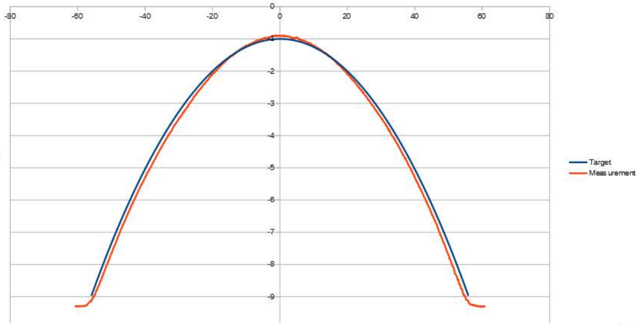

Blazed gratings

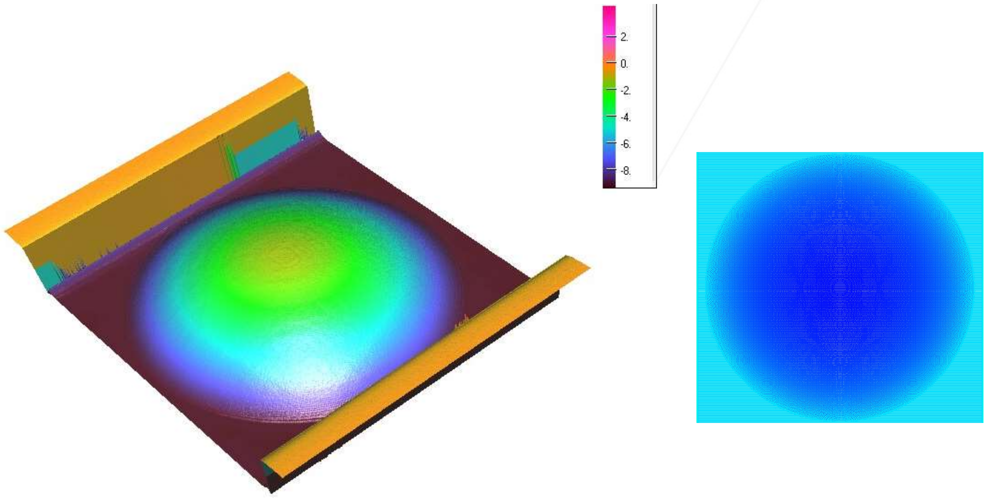
Courtesy of IMS


Fresnel lenses

Optical Lenses

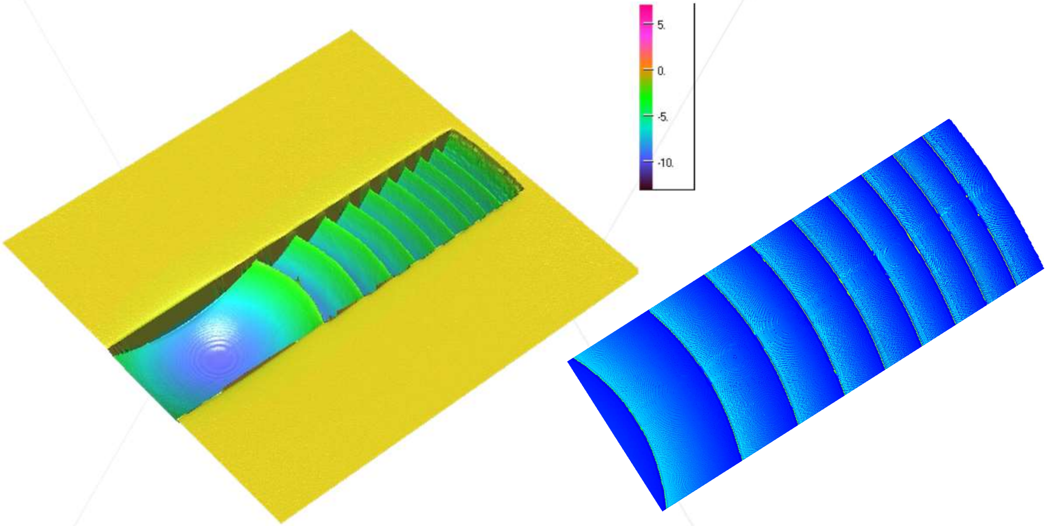
Convex Lens



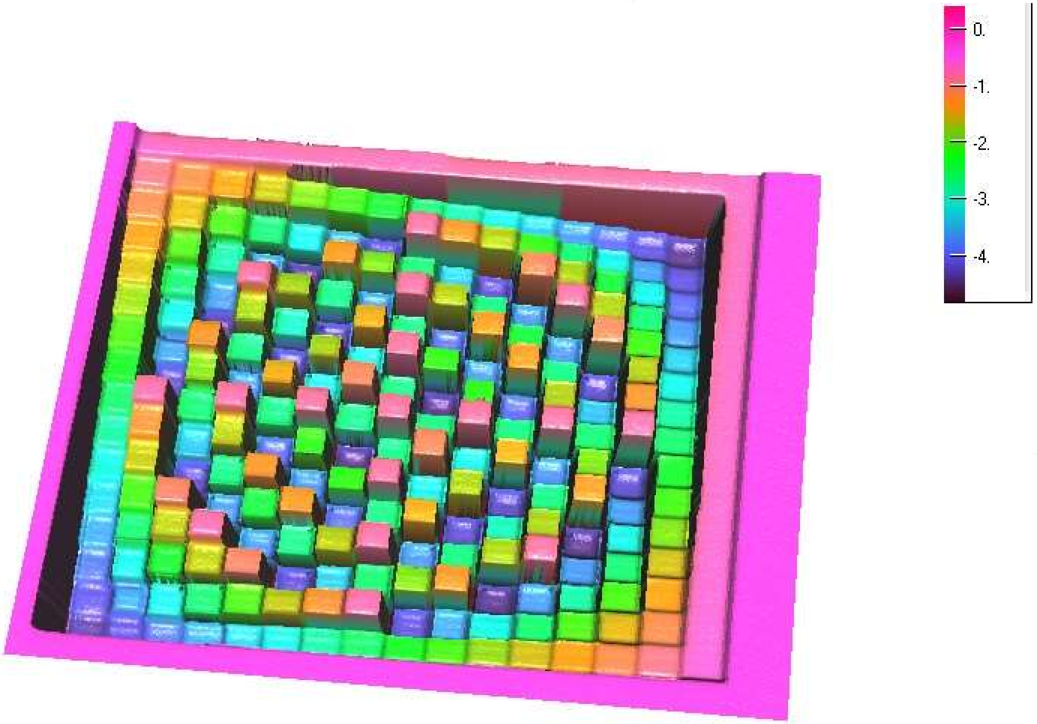


Courtesy of HIMT, Germany

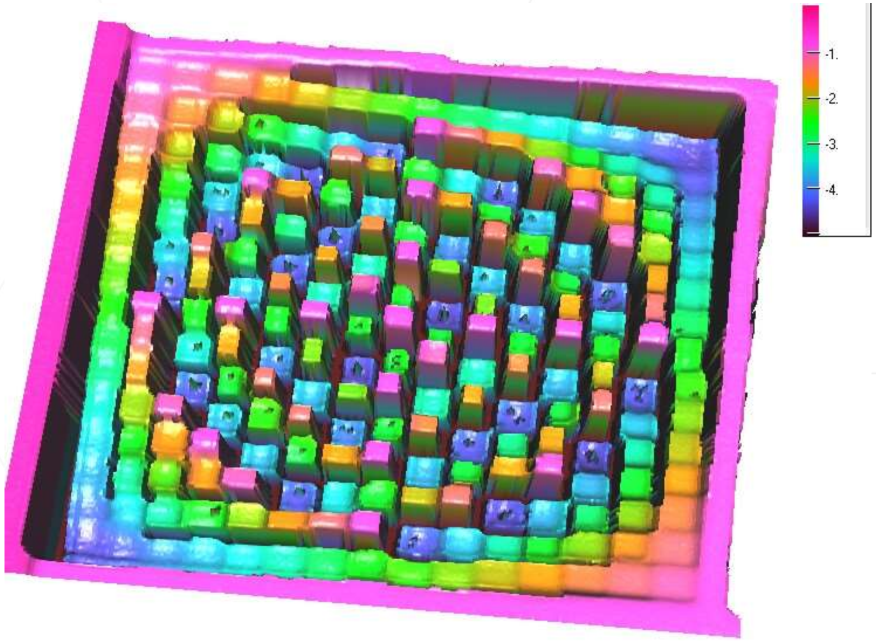
Fresnel Lens



Diffractive Optical Element



6.4 µm Squares/Pixels



3.2 µm Squares/Pixels

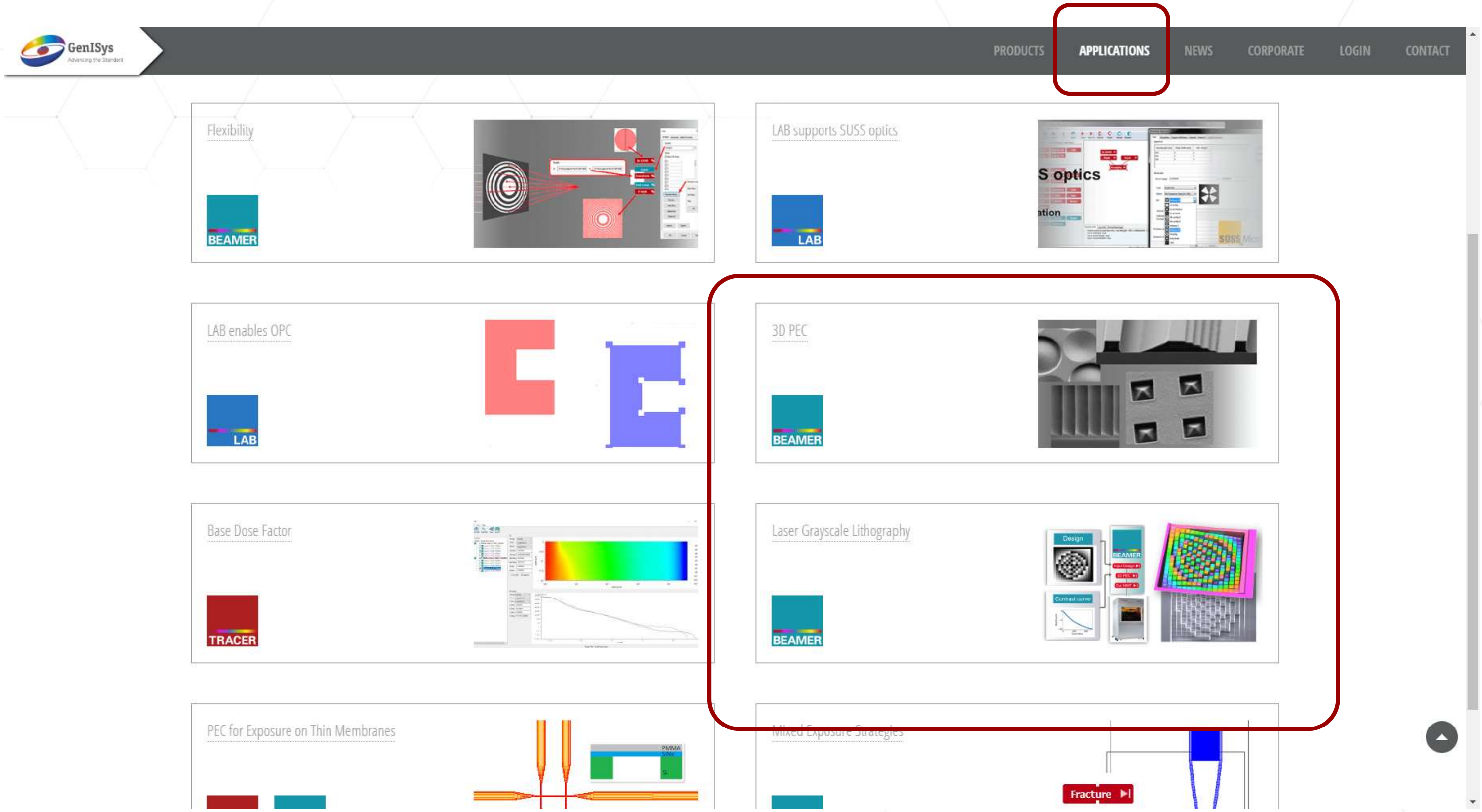
Courtesy of HIMT, Germany

Outline

- Part 5 Summary: Shape PEC – ODUS Contrast Enhancement
- Introduction to 3D Lithography
- 3D-PEC for E-Beam Lithography
- 3D-PEC for Laser Lithography
- Summary

Application Notes

GenISys website: www.genisys-gmbh.com



Summary

- 3D Surface PEC enables 3D Lithography with precise resist height control
  - computes effects of energy blur and scattering
- Selection of resist and process is important
- Additional effects to be considered & corrected include:
  - Tool and exposure effects
    - Multipass, Dose-Selective Multipass, and Overlap modes can reduce the impacts
  - PSF variation inside the resist
    - Using a 3D-PSF further improves accuracy to height targets
- With optimized correction, complex 3D structures can be fabricated
- This also applies to 3D-Laser exposures
  - Requires additional consideration of complex resist responses (surface inhibition, bleaching, focus variation)