GenISys
Advancing the Standard

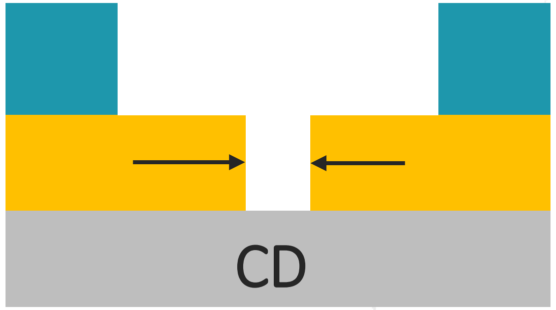
BEAMER

Building Bridges in BEAMER

using 3D Edge PEC

Problem Statement

- Objective
  - CD control in multilayer resist systems



- Requirements
  - Knowledge about the development behavior in the resist system:
  - →Development Rate Model

OUTLINE

- 3D Edge PEC
- Development Rate Model
- Lateral Development
- Case 1: How to Build a Bridge
- Case 2: Lift-off Undercut
- More cases

3D Edge Scenarios

Scenario 1: high D2C* bottom layer

e.g. T-Gate

**D2C = Dose-to-Clear*

Scenario 2: high D2C top layer

e.g. Dolan (shadow evaporation) technique

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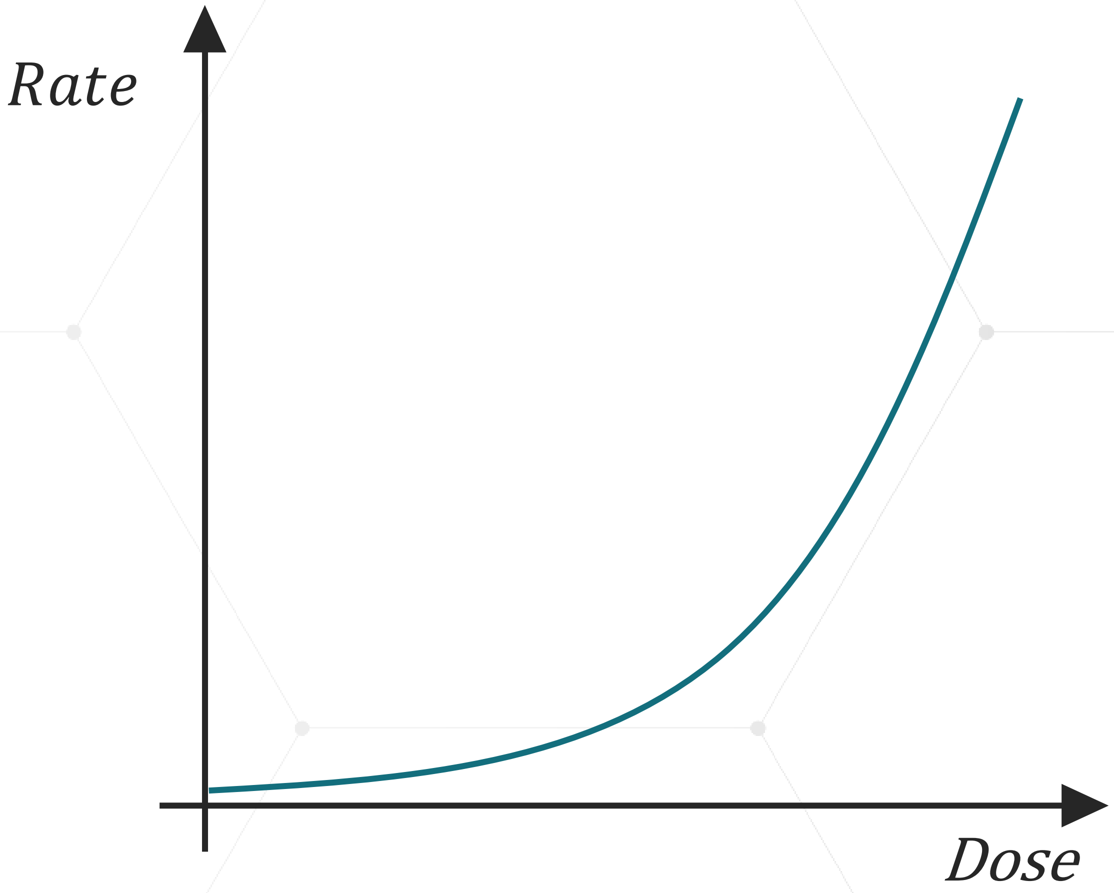
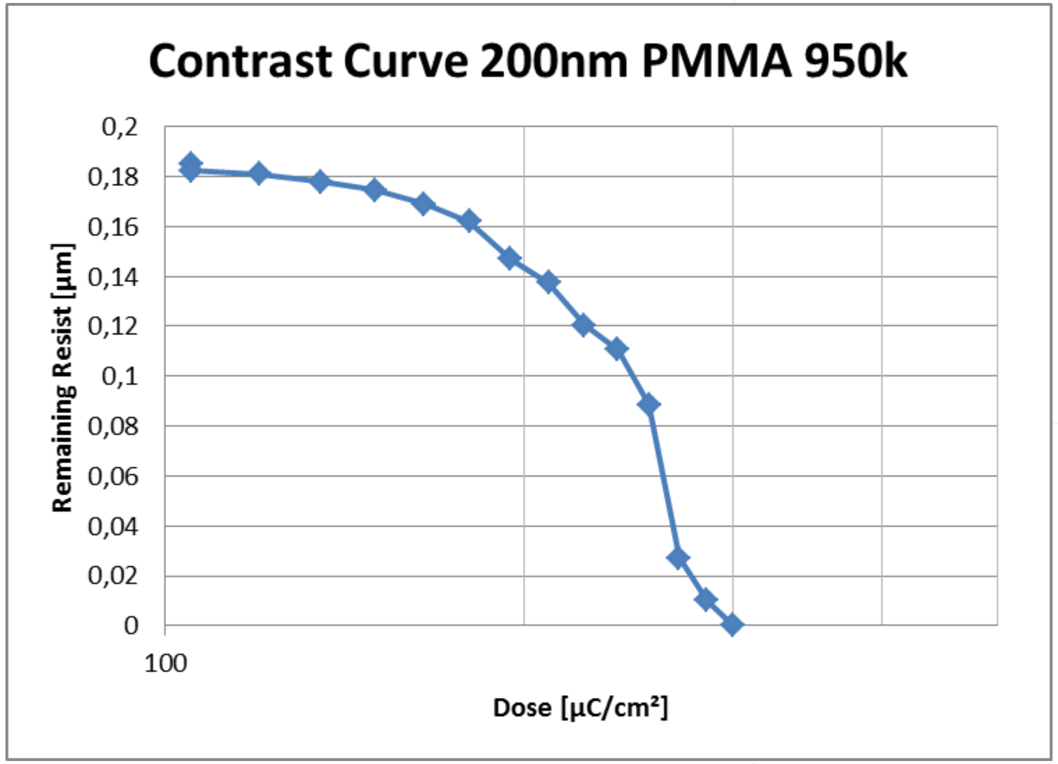
Development Rate Model (DRM)

- What is a DRM?
  - Describes the relation between applied dose and resist development: Rate(Dose).

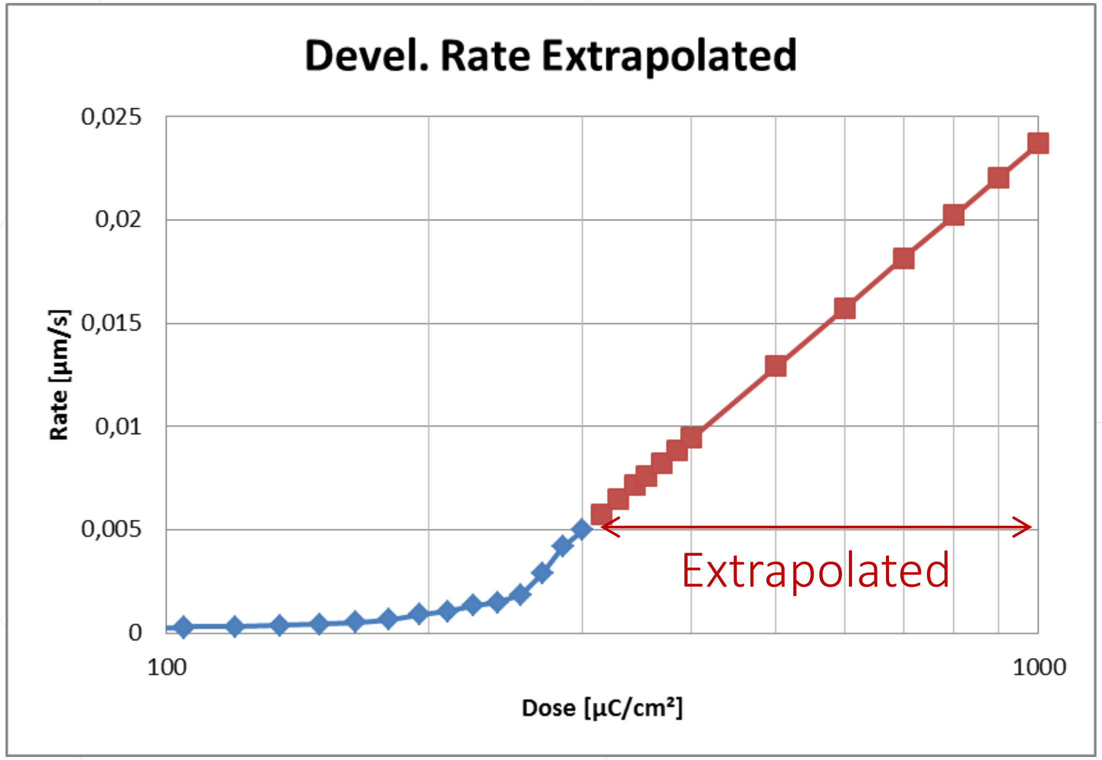


Development Rate Model (DRM)

- How do we get a DRM?



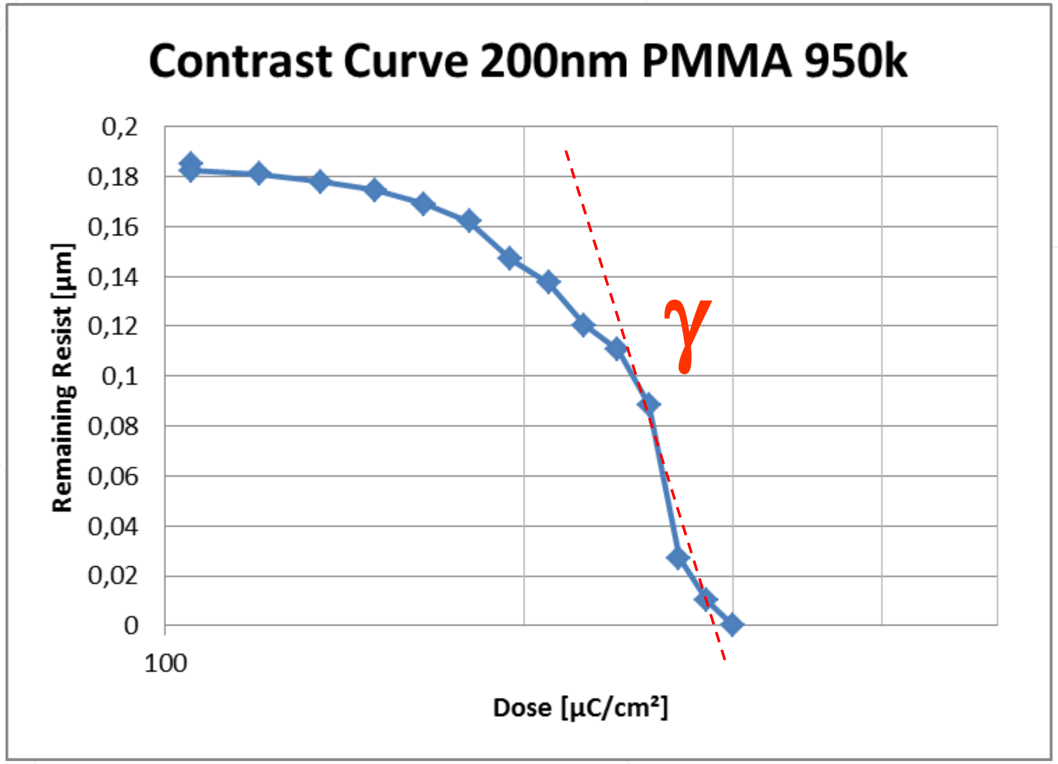
Fit



- Development Rates for higher doses have to be extrapolated from the given Contrast Curve.
- Knowing rates at higher doses is required as PEC might apply values higher than defined in CC

Development Rate Model (DRM)

- Which DRM is used in 3D Edge PEC?
  - Simple contrast model (Lumped Parameter Model):
  - $r = r_0 \left(\frac{D}{D_0}\right)^{\gamma}$;
  - D_0: Dose-to-Clear
  - r_0 : rate at D_0
  - γ : Contrast



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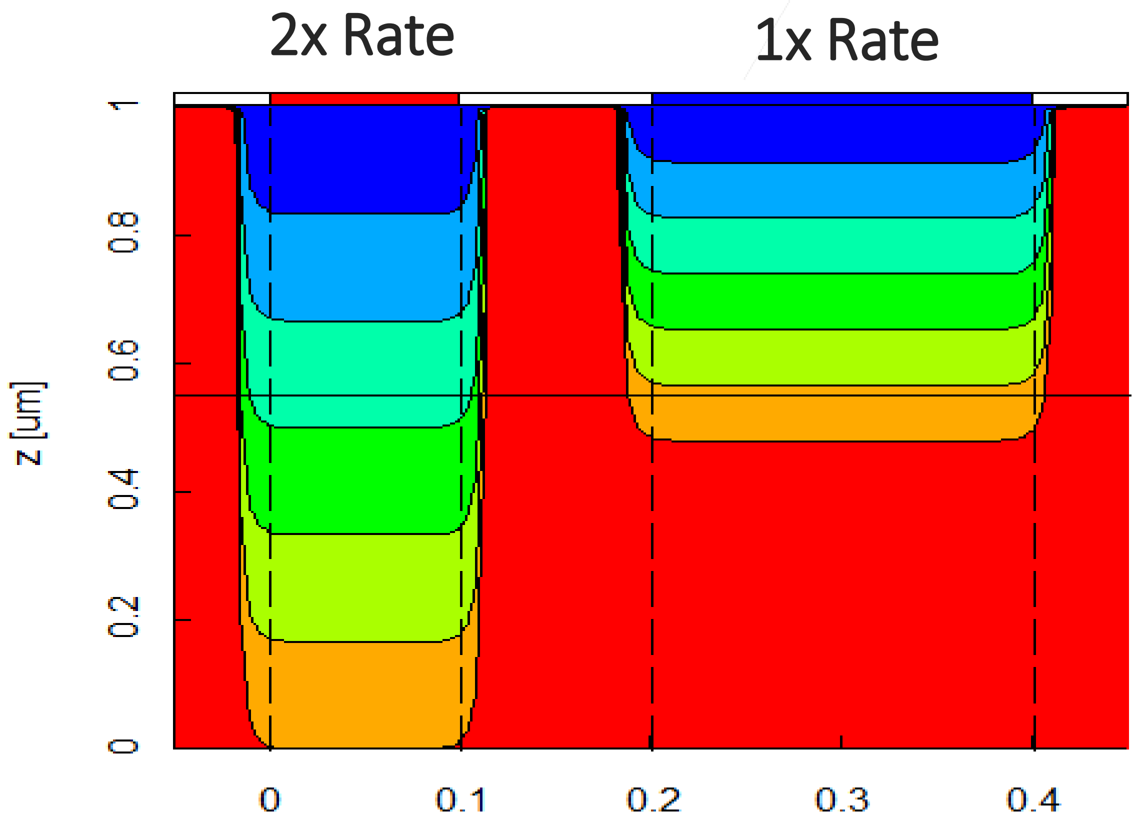
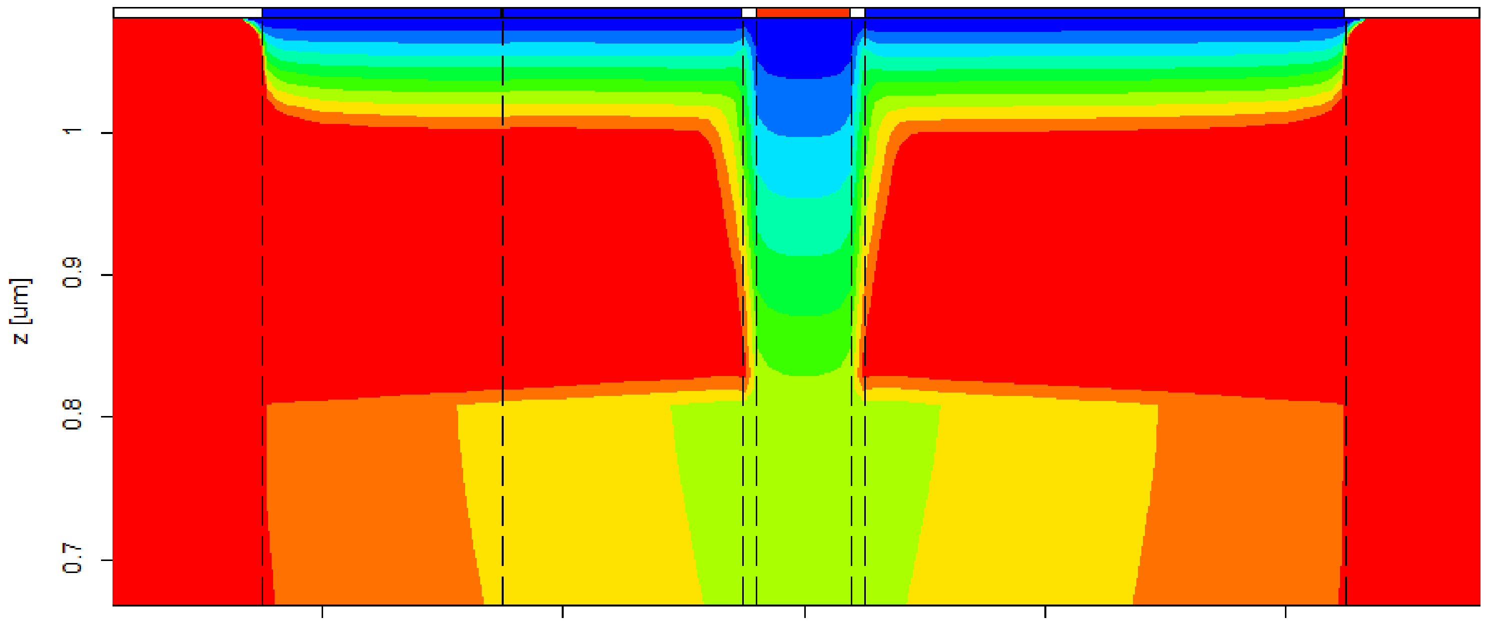
Lateral Development





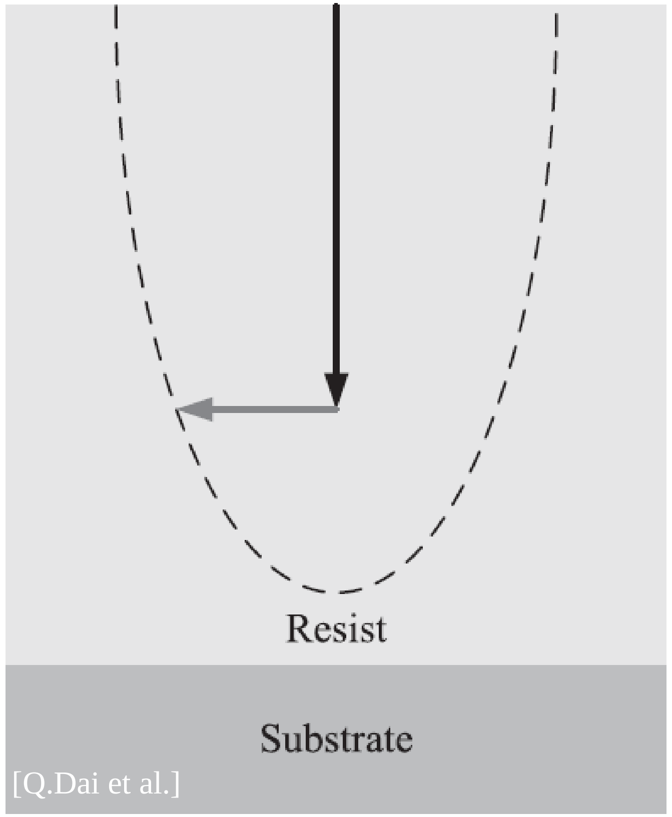
- **Example 1** :

  Regions with different removal rates.

- **Example 2** :

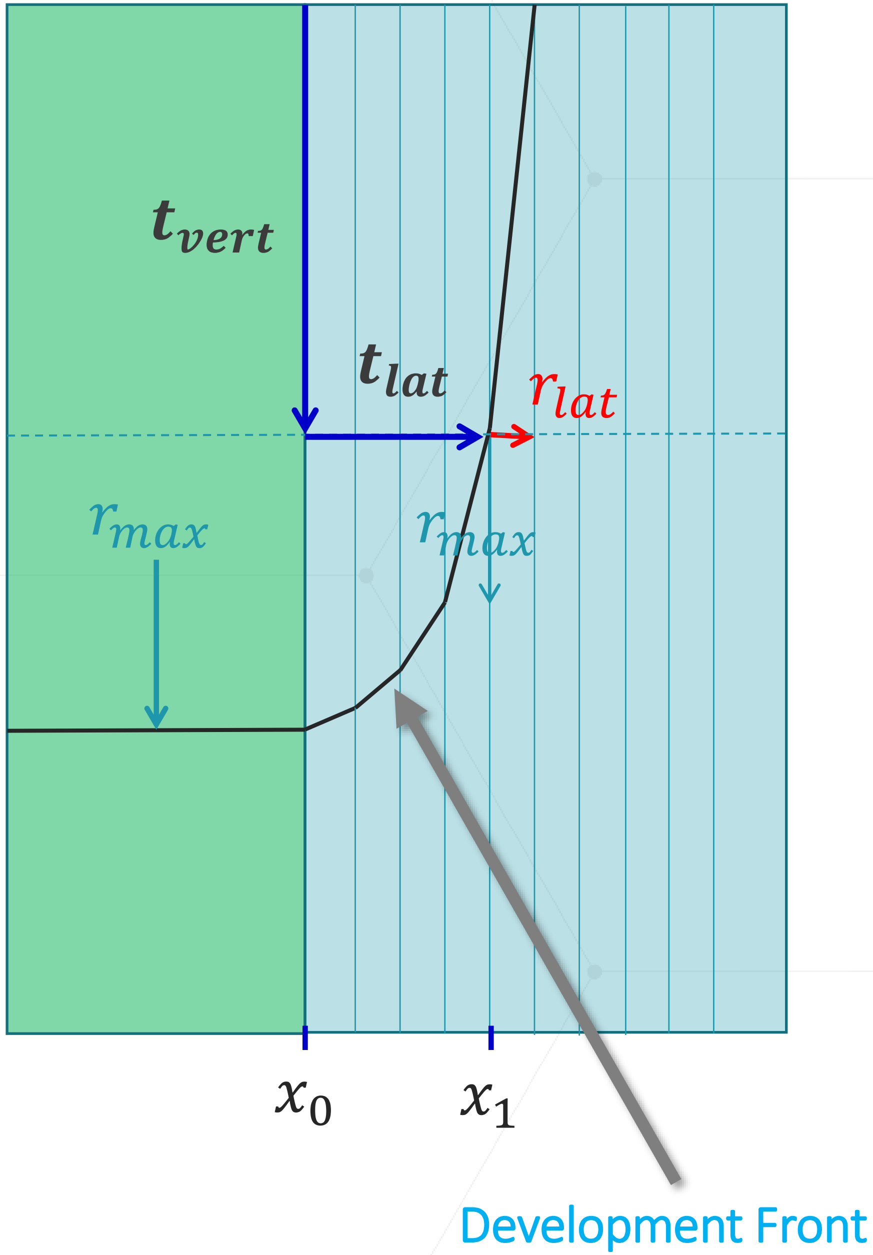
  In 3D applications regions with different rates are not separated, thus there‘s a huge impact!

Lateral Development Model



For the **development front** calculation, a **path based** method can be applied.

- Vertical path @ figure center with r_{max}.
- Horizontal path - lateral development using the rate profile $r_{lat}(x)$ obtained from dose profile.



t_{dev} : development time
t_{vert} : time for vertical path
t_{lat} : time for lateral path

$$t_{lat} = t_{dev} - t_{vert}$$

$r(x)$: local rate
r_{max} : max. rate in the middle
$r_{lat}(x)$: lateral rate

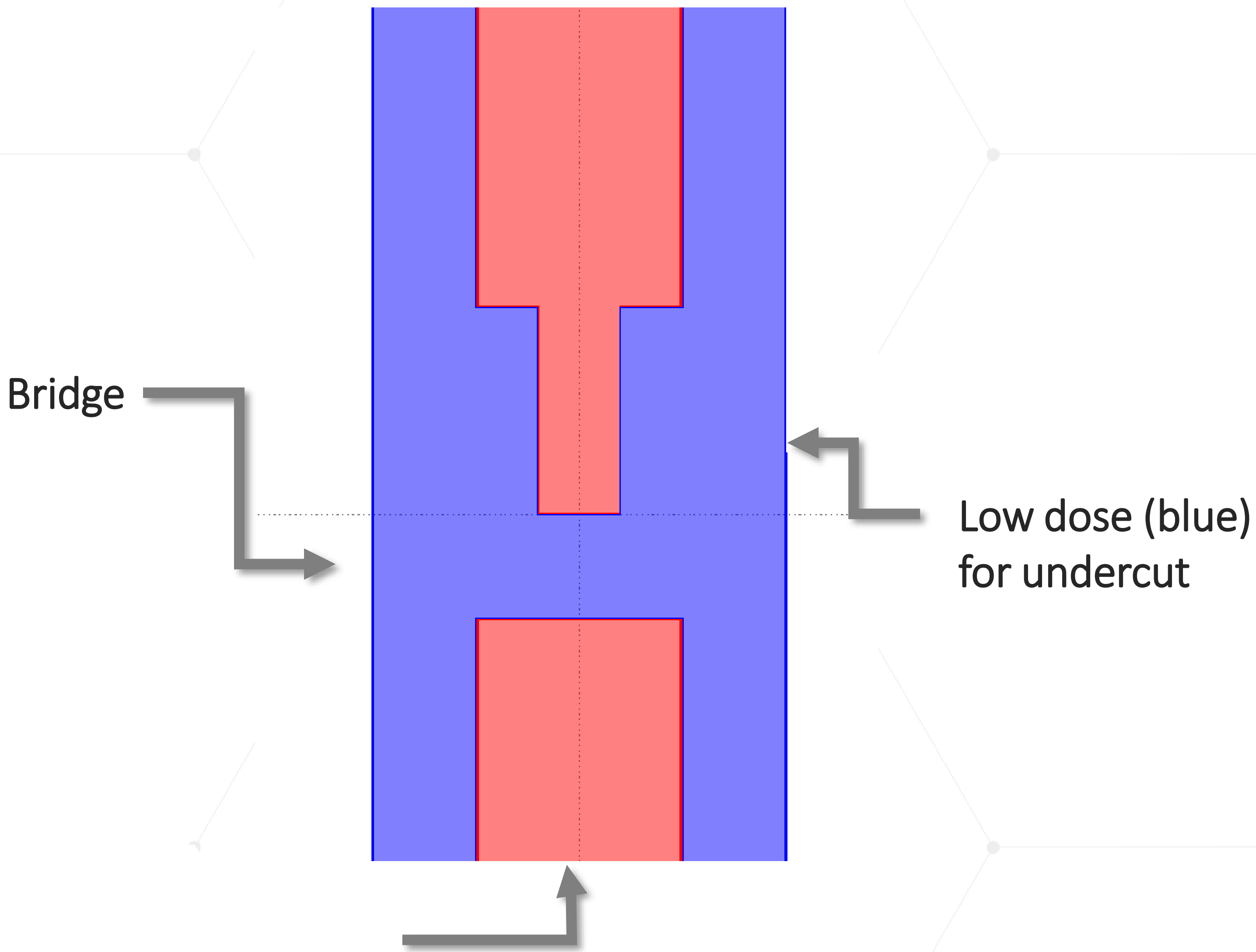
$$r_{lat} = r_{max} \tan\left(asin\left(\frac{r(x)}{r_{max}}\right)\right)$$

The amount of **lateral bias** (x1 – x0) at a defined resist depth is determined by integration:

$$t_{lat} = \int_{x_0}^{x_1} \frac{dx}{r_{lat}(x)}$$

Case 1: How to Build a Dolan Bridge

Case 1: Layout



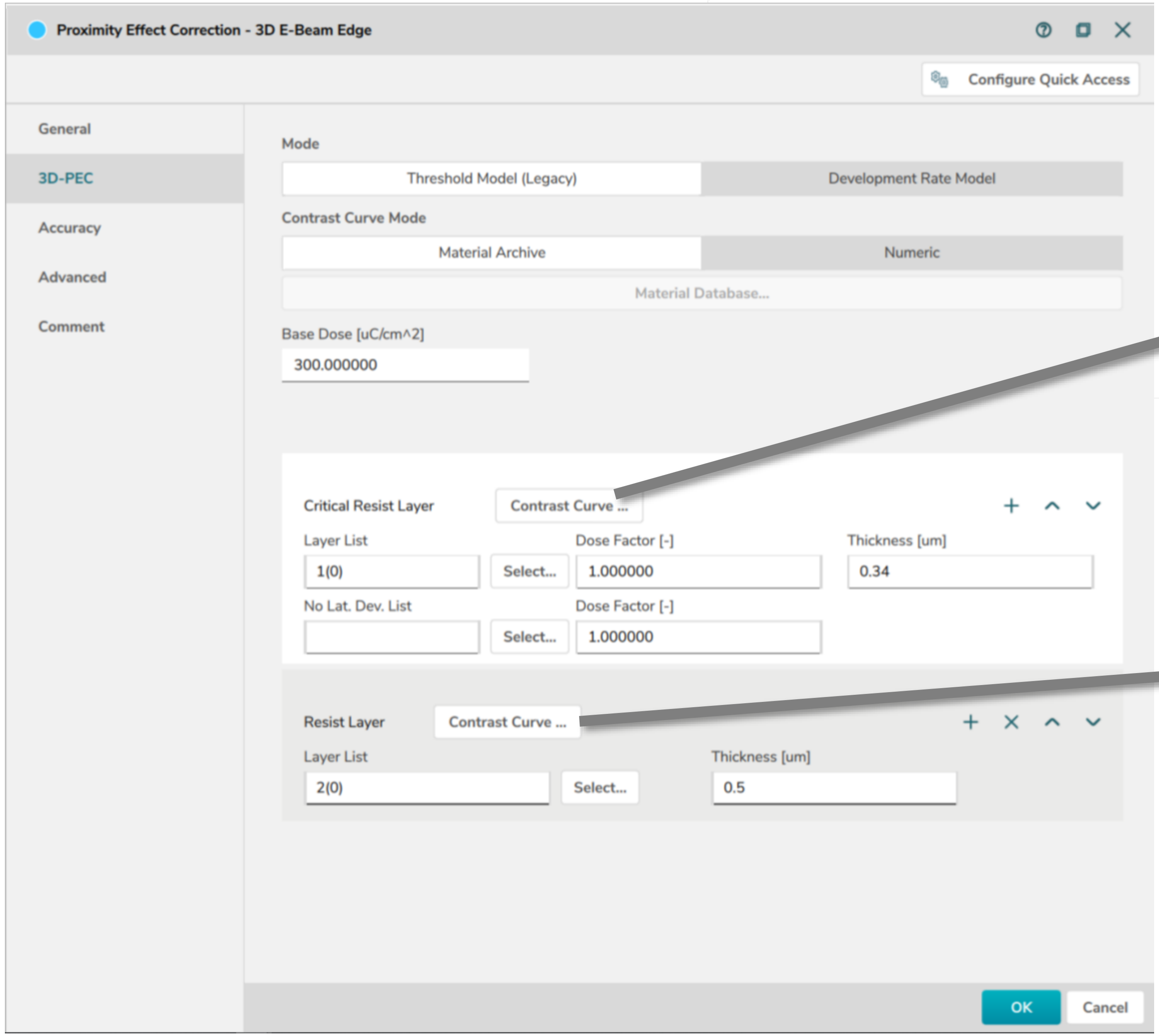
Bridge

Low dose (blue) for undercut

High dose (red) for defining the bridge

Case 1: Resist layers

3D E-Beam Edge



Proximity Effect Correction - 3D E-Beam Edge

Mode: Threshold Model (Legacy) | Development Rate Model

Contrast Curve Mode: Material Archive | Numeric

Base Dose [uC/cm^2]: 300.000000

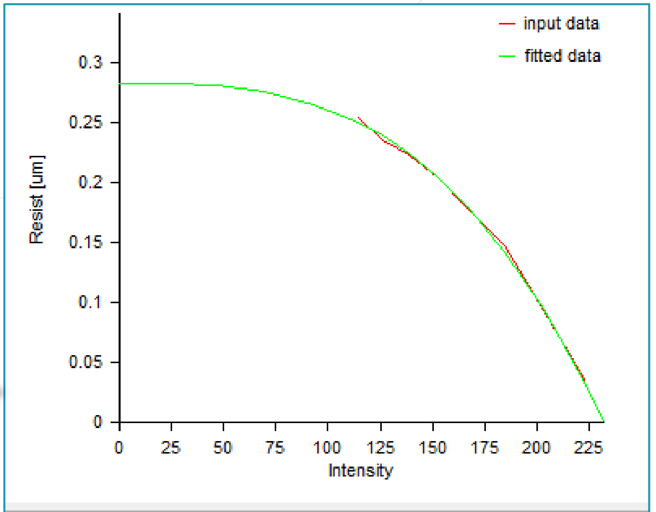
Critical Resist Layer — Contrast Curve ...

Layer List: 1(0) Select... Dose Factor [-]: 1.000000 Thickness [um]: 0.34

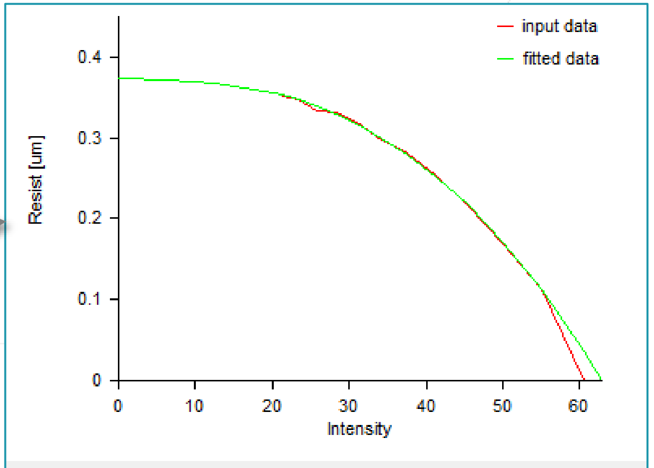
No Lat. Dev. List: Select... Dose Factor [-]: 1.000000

Resist Layer — Contrast Curve ...

Layer List: 2(0) Select... Thickness [um]: 0.5

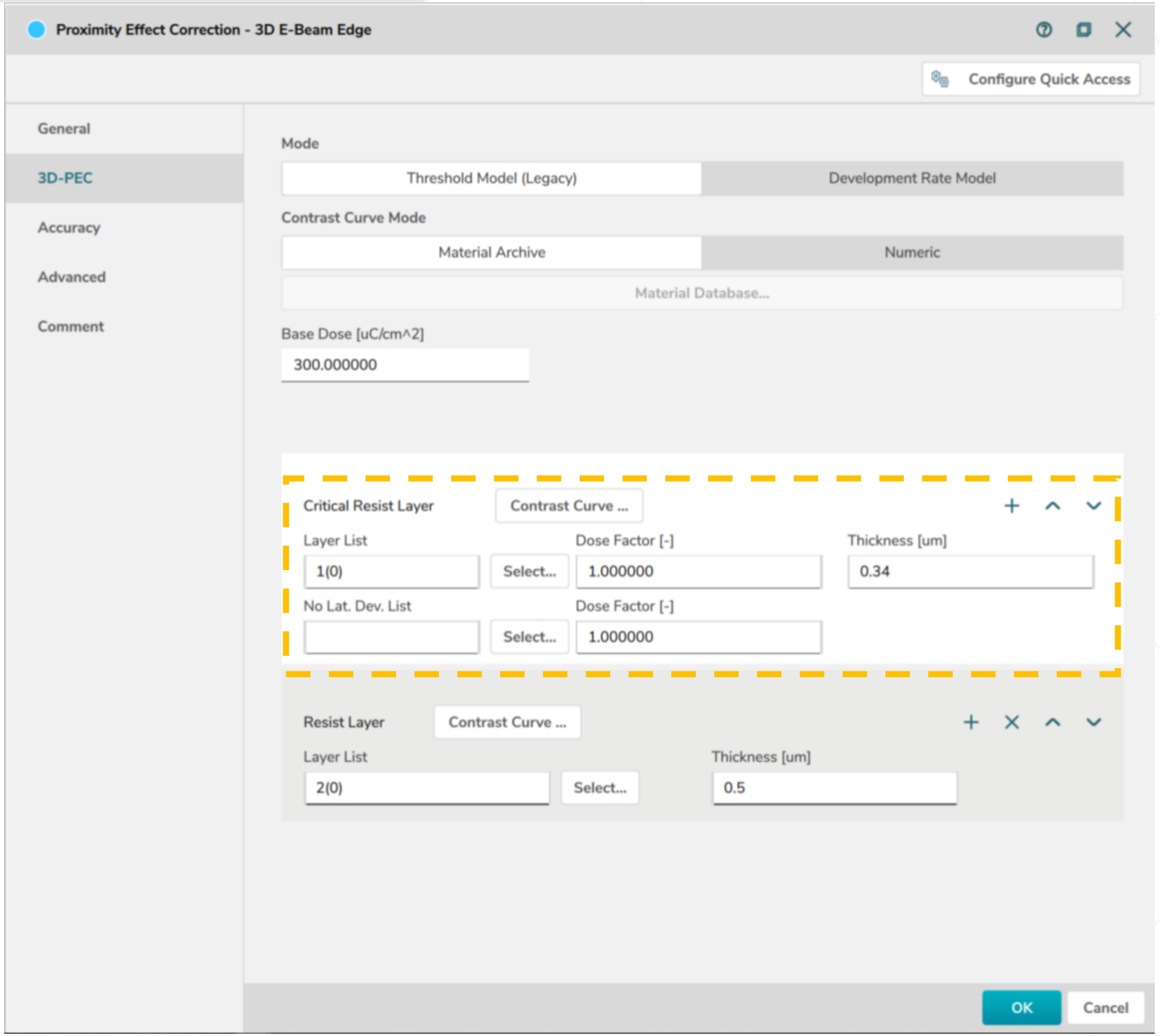


Fitted contrast: 3.06, thickness: 0.2832, D0: 231.9, RMS [um]: 0.003071.



Fitted contrast: 2.67, thickness: 0.373, D0: 62.85, RMS [um]: 0.0107.
Table rows with resist thickness <5% of the full thickness have been ignored for fitting

Case 1: Critical Layer



Proximity Effect Correction - 3D E-Beam Edge

Mode: Threshold Model (Legacy) | Development Rate Model

Contrast Curve Mode: Material Archive | Numeric

Base Dose [uC/cm^2]: 300.000000

Critical Resist Layer
Layer List: 1(0)
Dose Factor [-]: 1.000000
Thickness [um]: 0.34
No Lat. Dev. List:
Dose Factor [-]: 1.000000

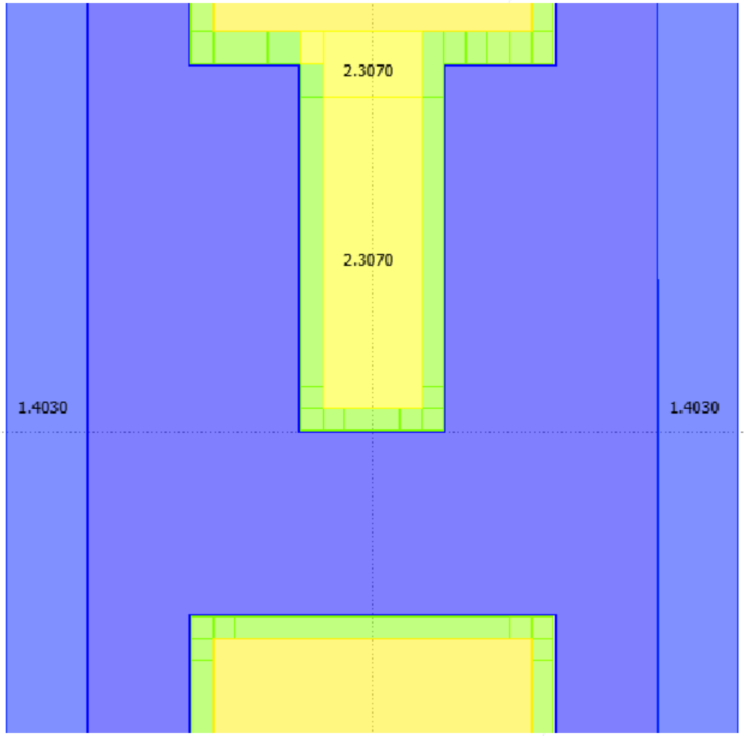
Resist Layer
Layer List: 2(0)
Thickness [um]: 0.5

The **critical layer** that includes exact **lateral development** compensation can be placed anywhere in the stack.

The “critical” resist layer allows for overdose/undersize. Still some regions, e.g. contacts, can be excluded from the lat. dev. computation. -> “No Lat. Dev. List”.

The “non critical” layers, e.g. undercut, are optimized for resist removal (dose-to-clear from contrast curve) but do not exact CD. So lat. dev. Is discarded there.

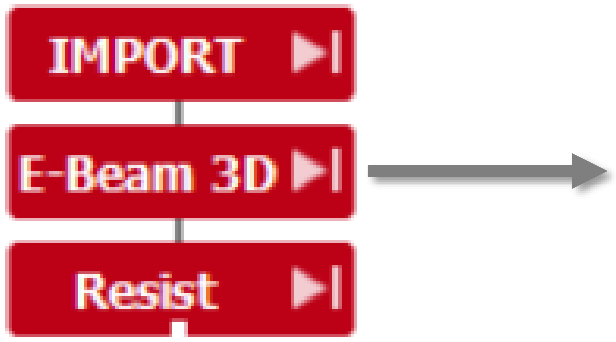
Case 1: Export Corrected Pattern

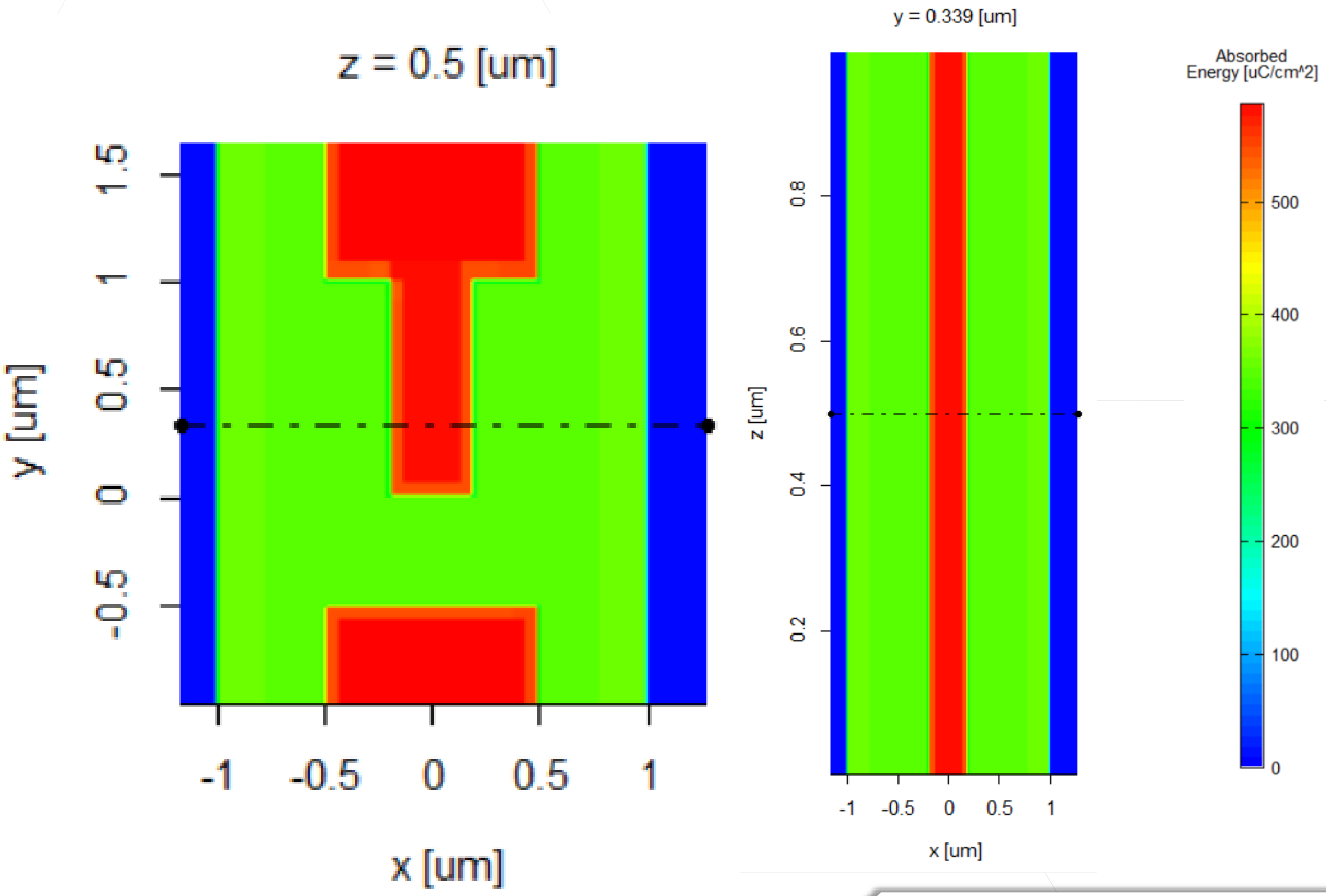


BEAMER

LAB

Case 1: 3D E-beam simulation



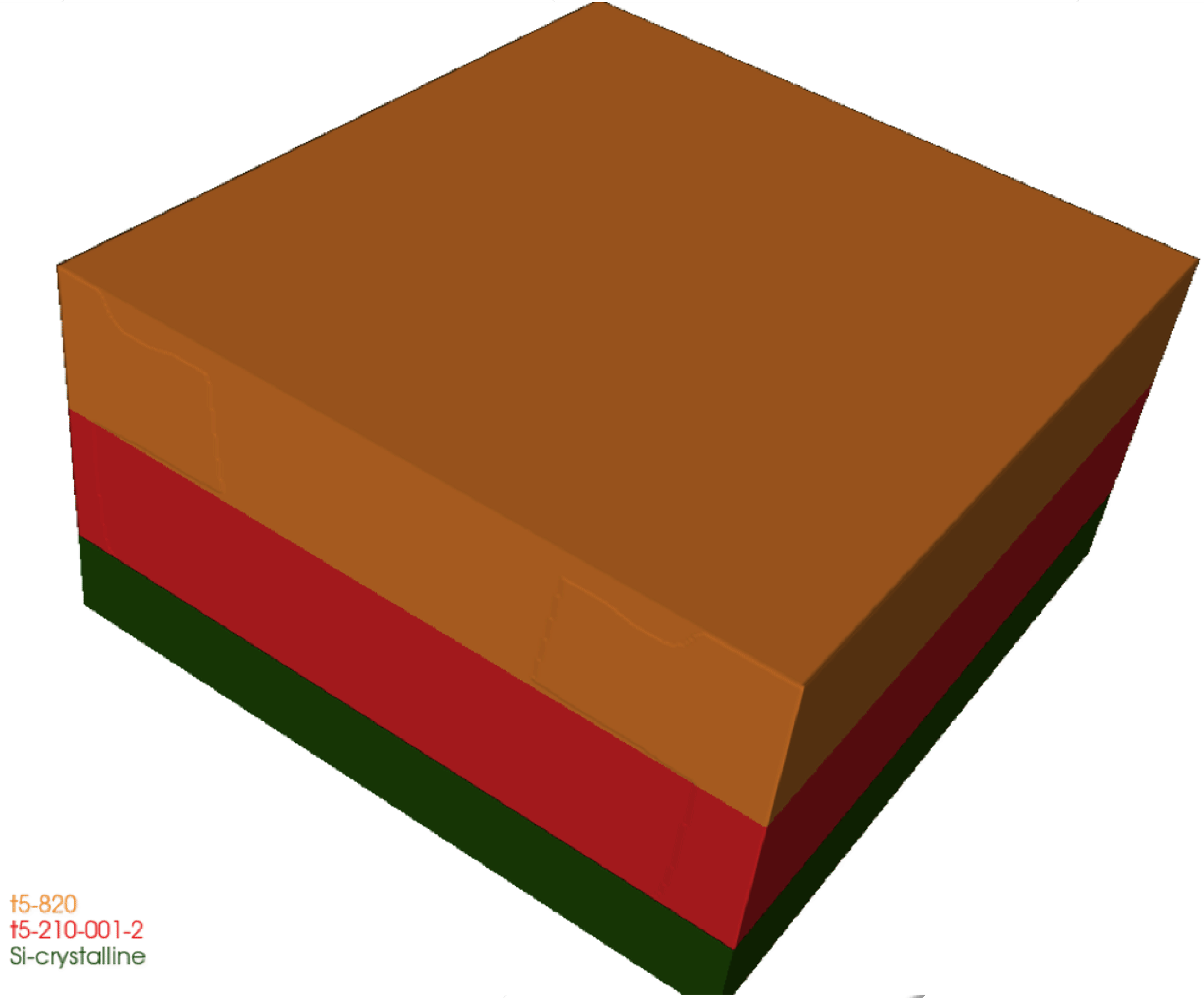


Case 1: 3D Resist Simulation

IMPORT ▶|

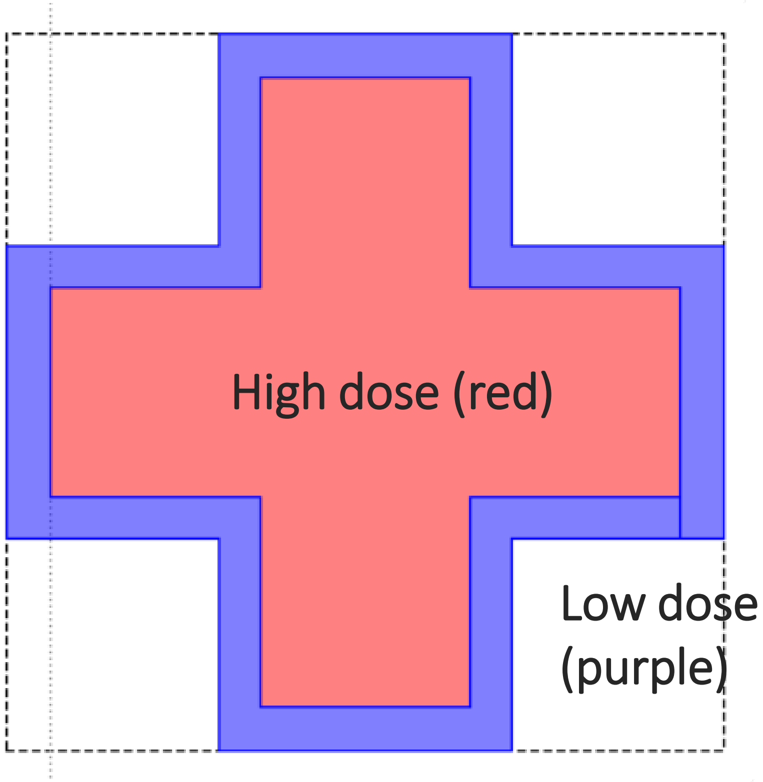
E-Beam 3D ▶|

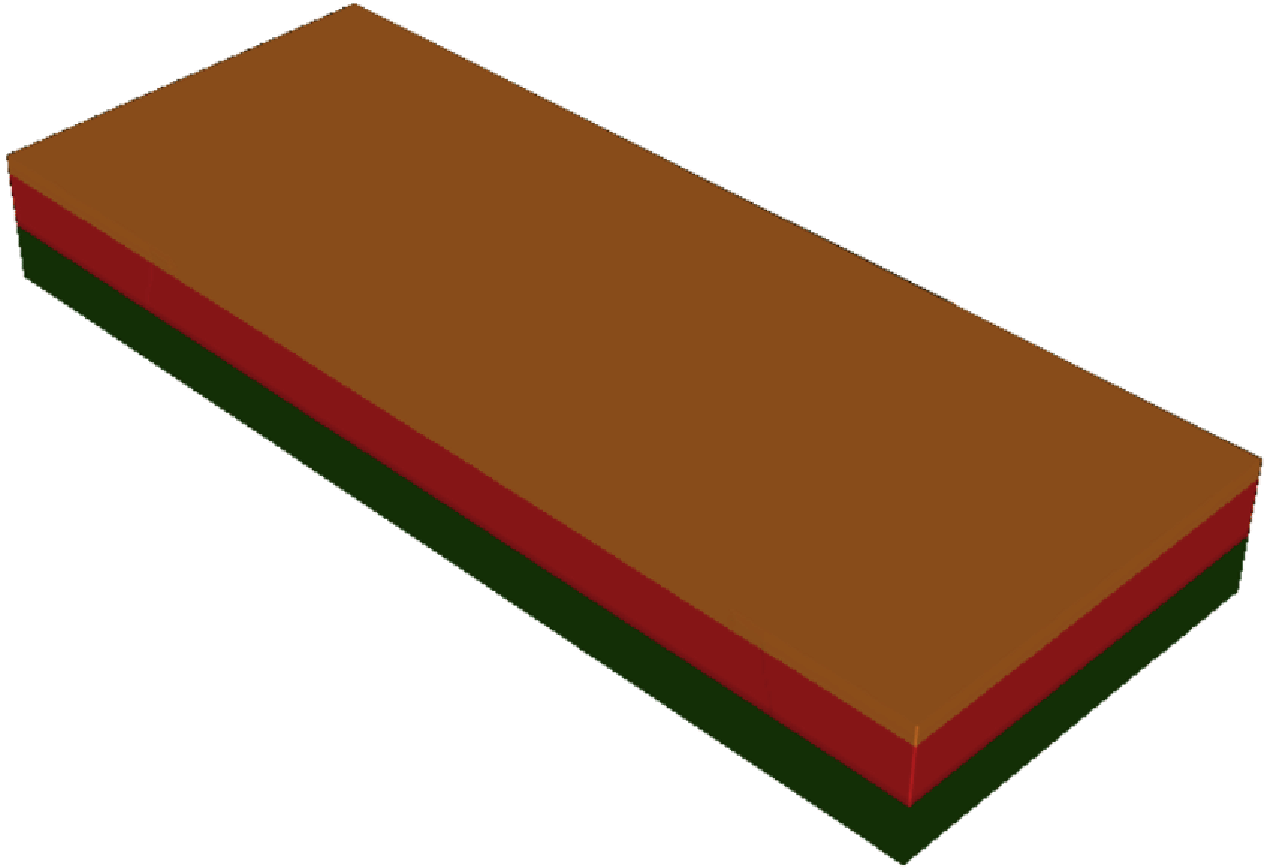
Resist ▶|



Case 2: Lift-off undercut

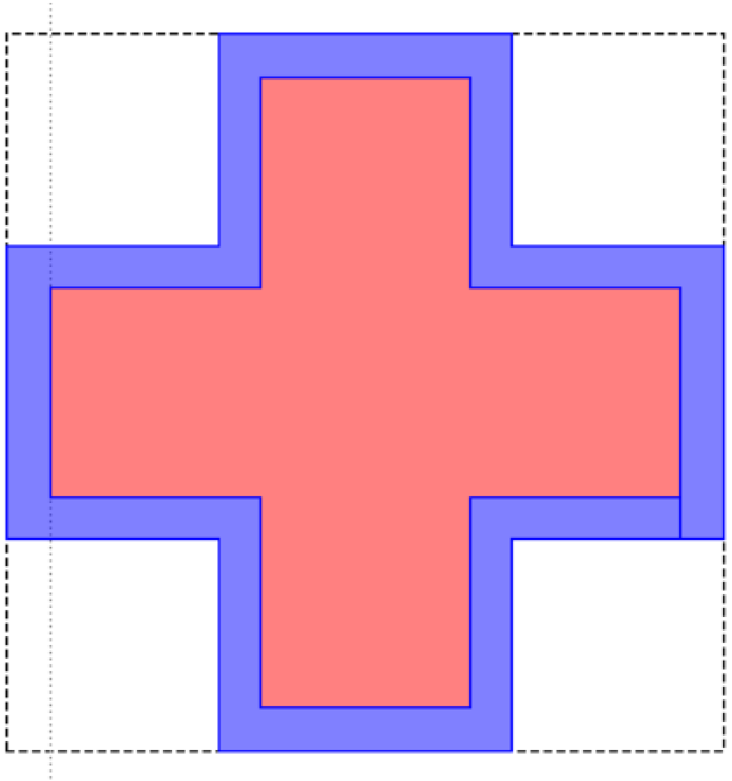
Case 2: Lift-off Undercut

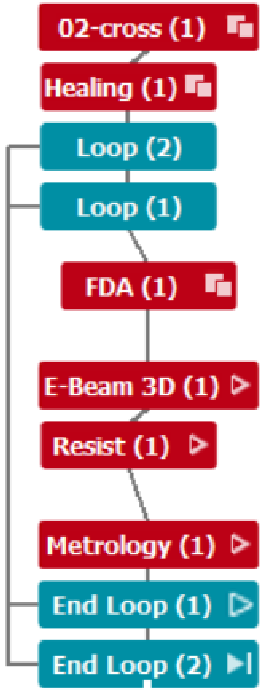




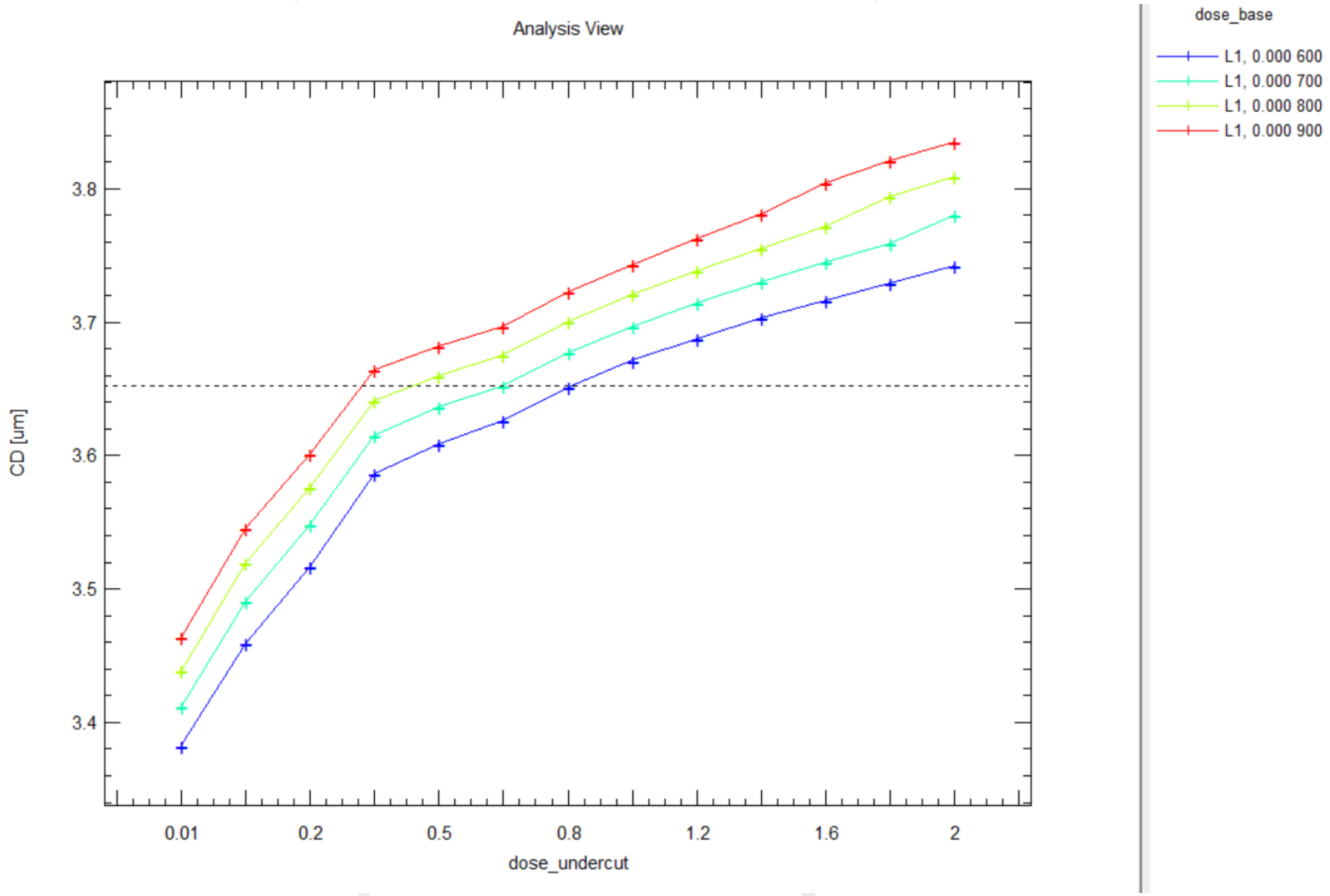
t5-820
t5-210-001-2

Case 2: Lift-off Undercut





02-cross (1)
Healing (1)
Loop (2)
Loop (1)
FDA (1)
E-Beam 3D (1)
Resist (1)
Metrology (1)
End Loop (1)
End Loop (2)



Automated exploration of parameters

Other Cases:

- Multilayer Resist Systems:
  - Bilayer: one developer
  - Bilayer: two developers
  - Trilayer: one developer [1]
  - Trilayer: two developers
  - Trilayer: three developers

- Ref [1]: Ocola et al., “Trilayer process for T-gate and Γ-gate lithography using ternary developer and proximity effect correction superposition”, J. Vac. Sci. Technol. B 40, 062605 (2022)

Thank You!

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