Study influential factors on lithography imaging in implant layers with wafer topography

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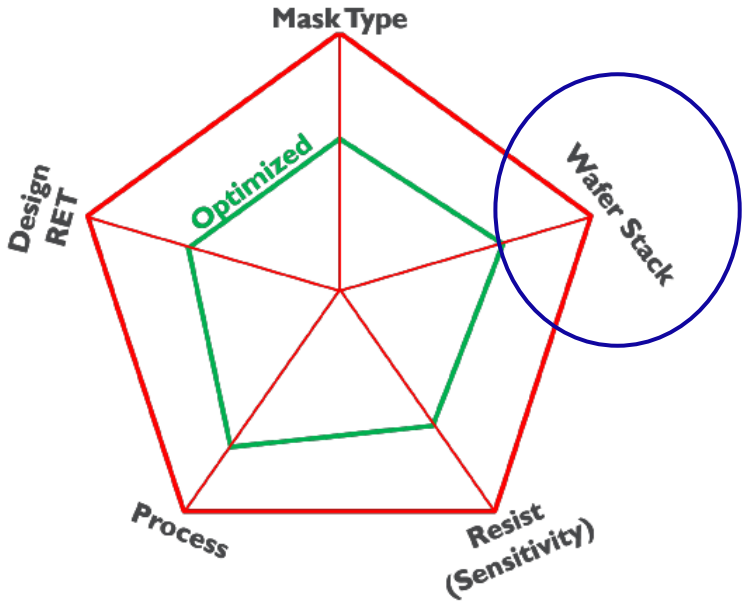
Outline

- Introduction
- Topography effect on lithography imaging using planar waves
- Pupil Illumination with topography effects
- Summary

Introduction

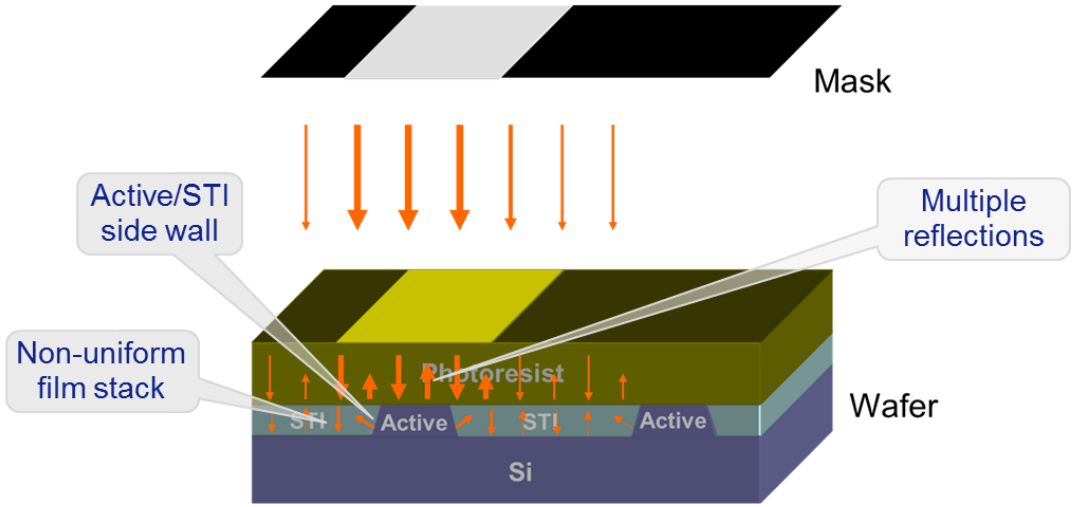
Topography effects from wafer stack

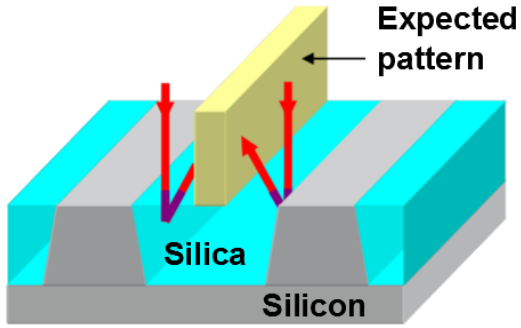
Wafer stack, resist thickness and underlayers impact imaging formation.

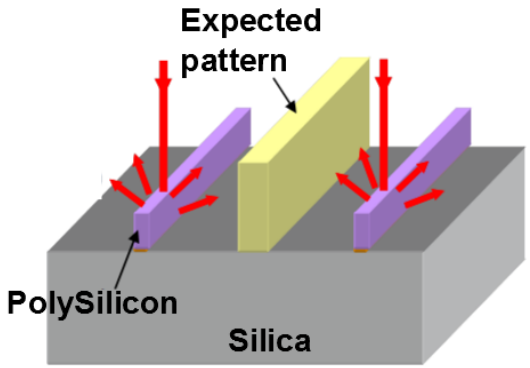


Common pentagon trade-off relationship for patterning.

Wafer topography effect if no BARC



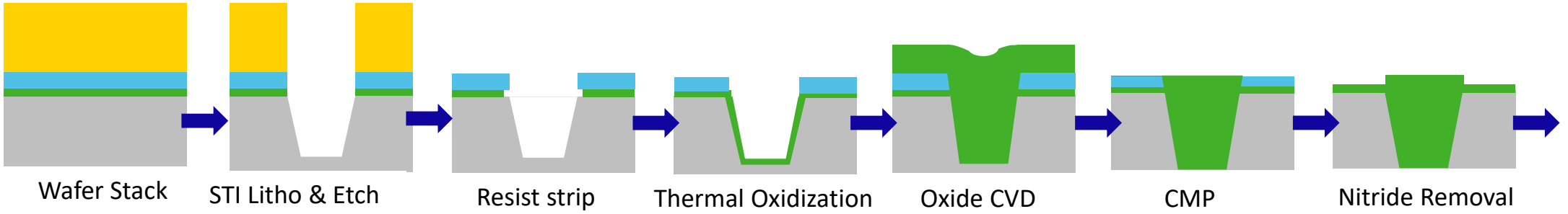


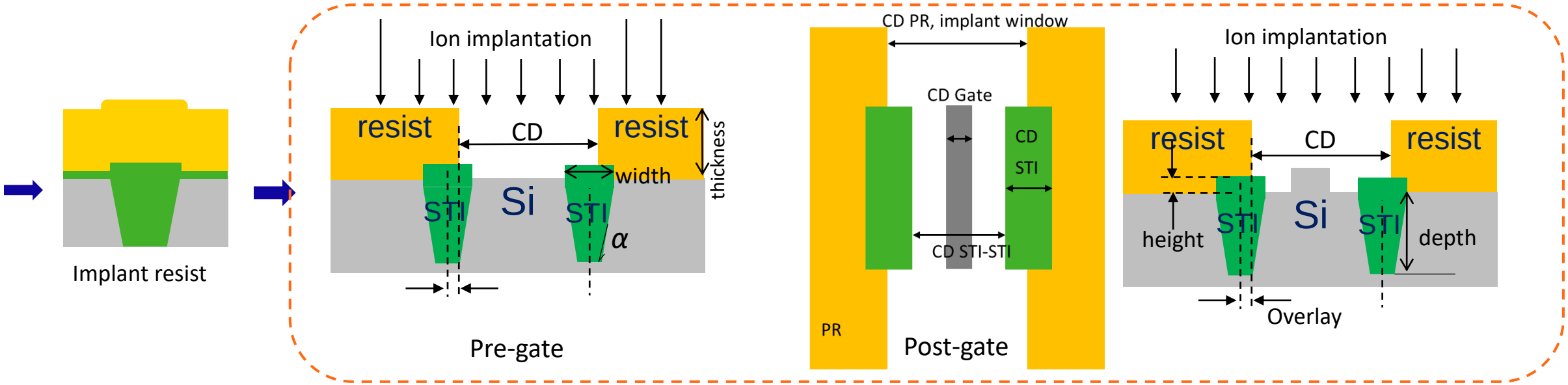


Ref, doi: 10.1117/12.2614268; 10.1117/12.2552102

Process Flow of Implantation Layer without BARC

Typical STI process flow, pre-gate and post-gate.





*We take KrF 248 nm for the following study.

Challenges

What if no BARC?

- Imaging formation can be easily disturbed by many parameters: resist thickness, resist n, k, wafer topography, overlay, focus schemes, et al.
- Further consequence for implantation:
  - resist profile instability
  - bottom CD variation
  - Ion scattering fingerprints, kind well proximity error
  - yield of the electrical performance

Can changing imaging conditions help better patterning with these effects?

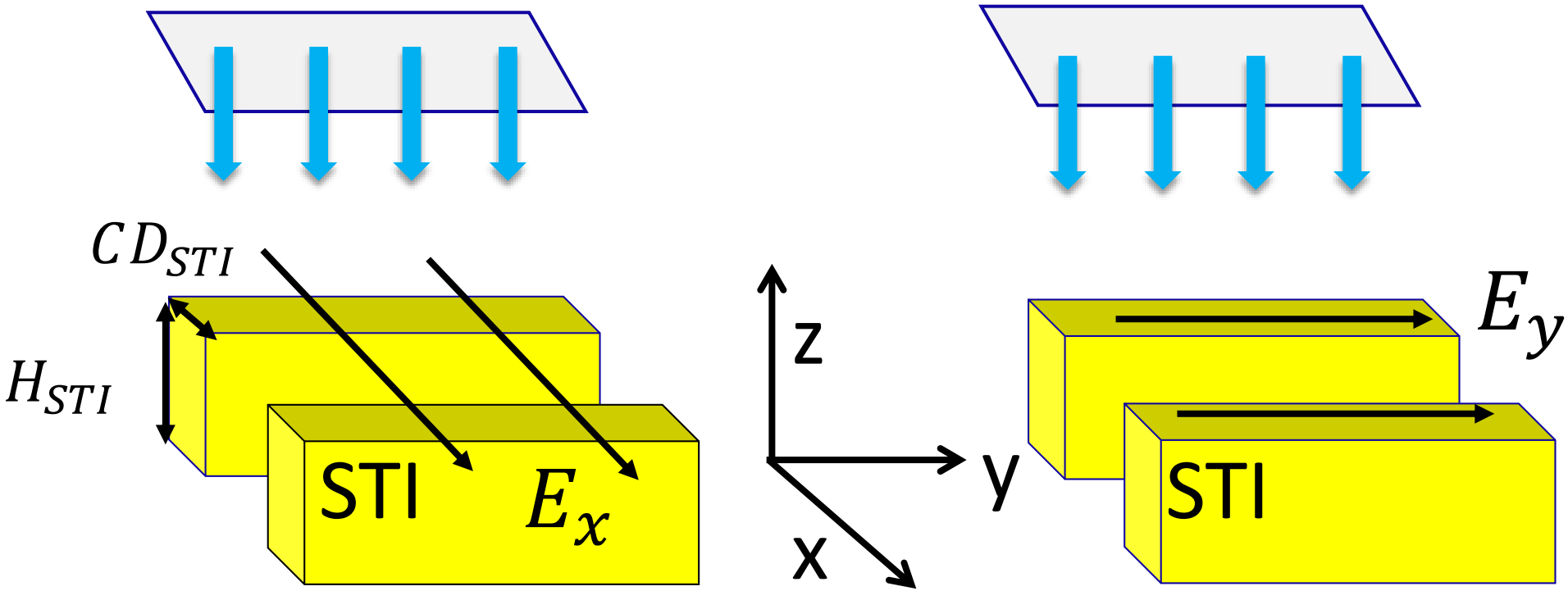
How these factors influence on lithography imaging (resist profiles and CD)?

What are the insights learn to carry out optimizations and mitigate the influences?

Planar Wave Illumination for Waveguide Effects

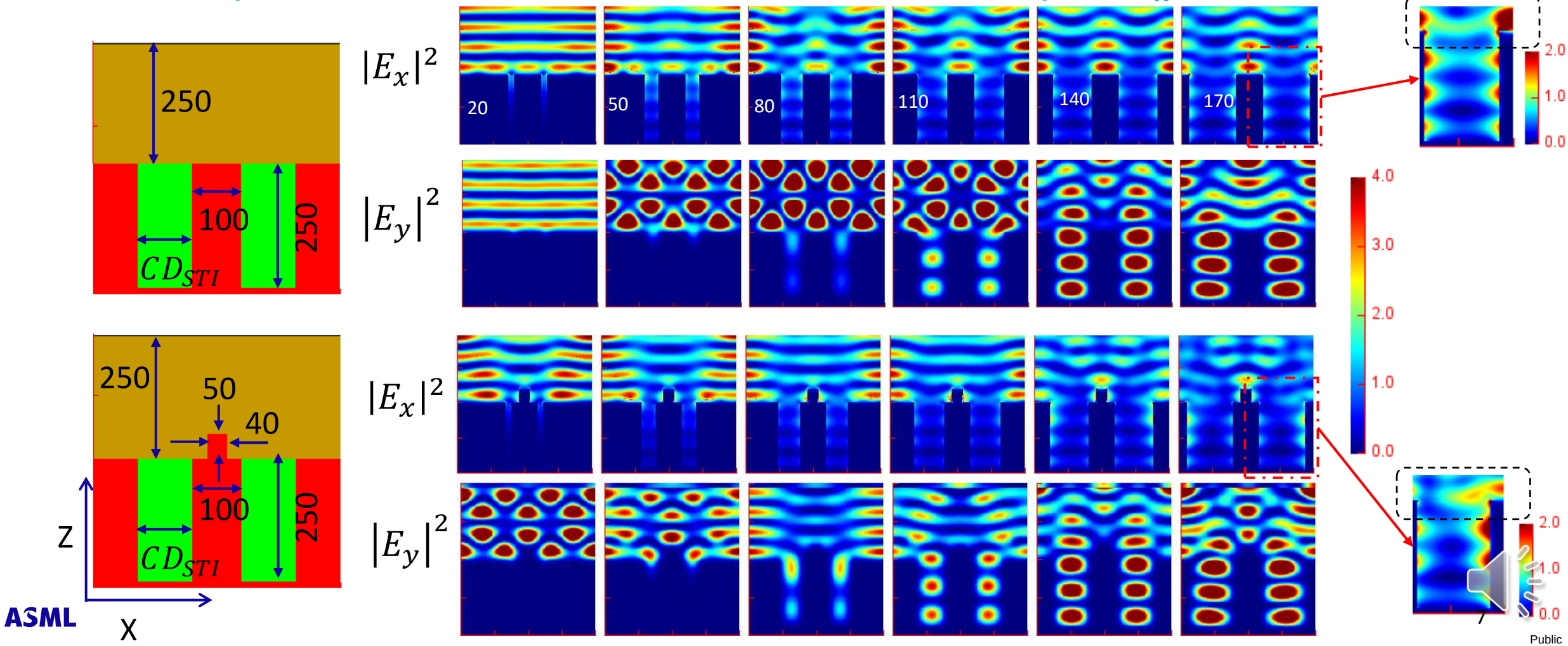
X-polarized light tends to have an interaction with the STI trenches but no travelling at SiO_2/Si interface → waveguide effects.

Y-polarized light propagates all the way through the STI trenches and interacts the STI bottom → STI related standing wave.



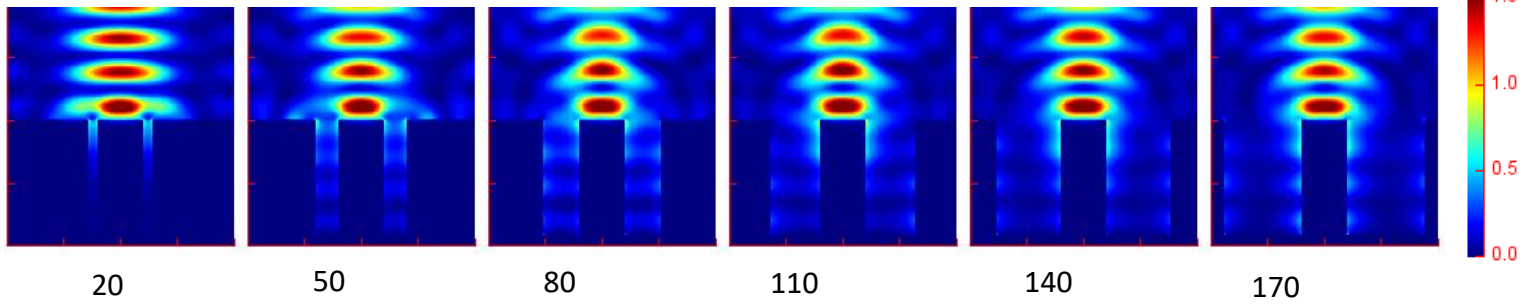
Waveguiding and Reflections of Planar Wave

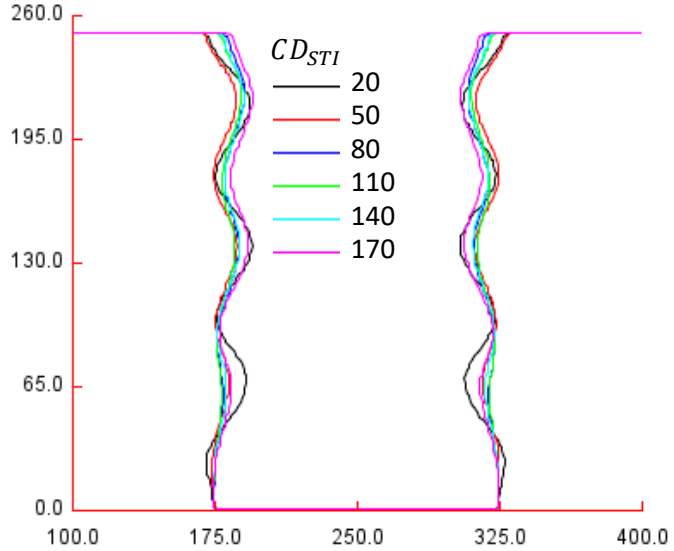
- Y-polarized light → strong STI related standing wave from bottom interface
- X-polarized light couples into the STI while Y-polarized cut-off for narrower STI
- Gate helps to reduce reflection at resist bottom, mainly for E_x



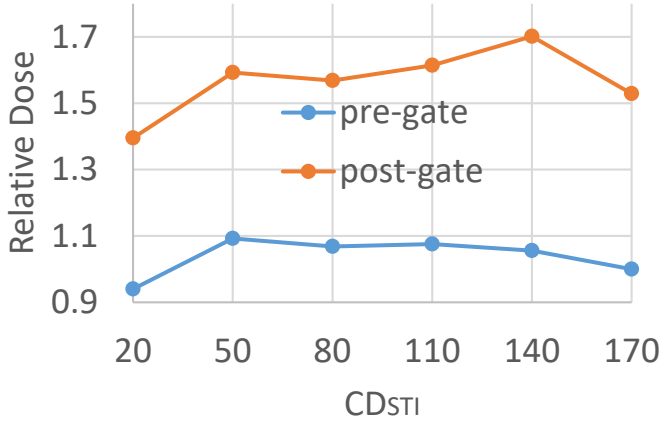
On-axis E_x Planar Wave Illumination with A Mask

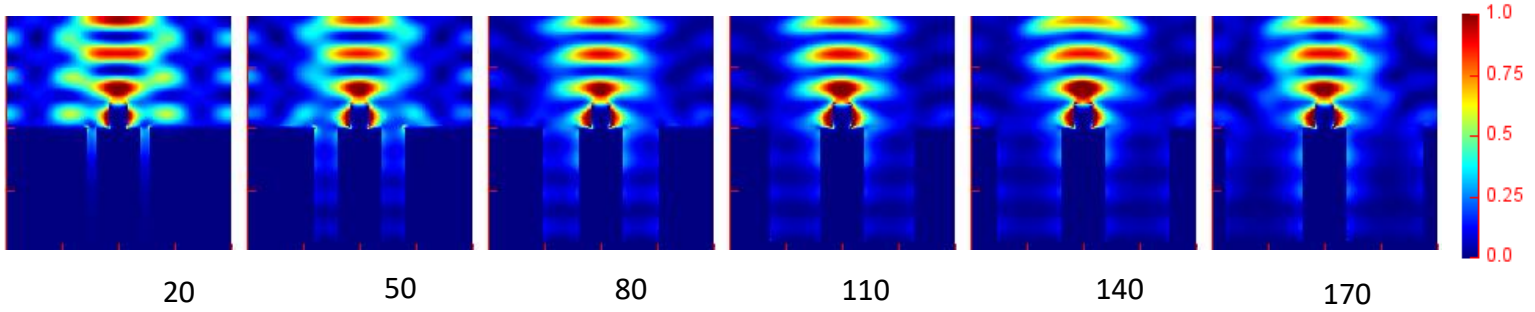
Line pattern: CD=150, pitch=500.

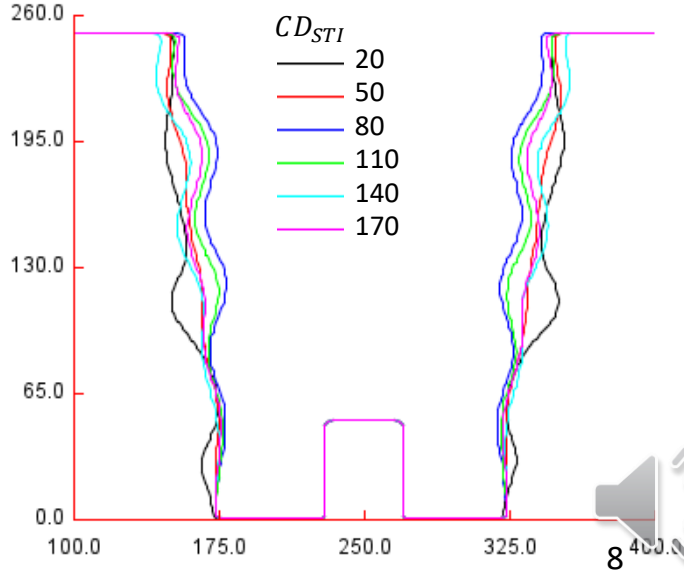




- Narrower CD_{STI}, stronger standing wave pattern in profiles due to surface reflections.
- Gate contributes to destruct the reflection at resist bottom at some range of CD_{STI}
- Pre- and post-gate show similar dose variation trends



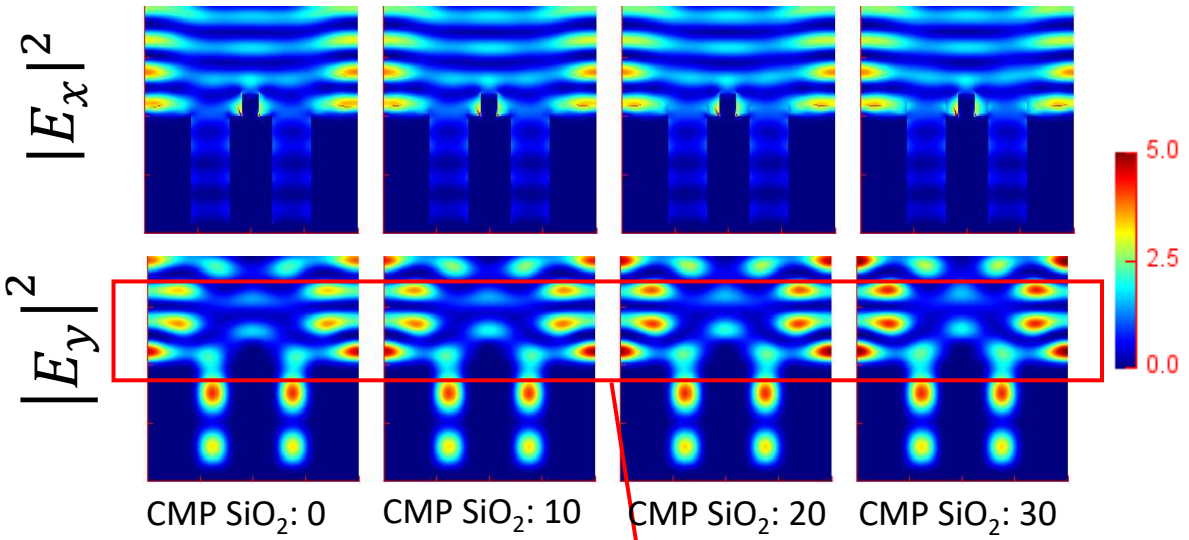


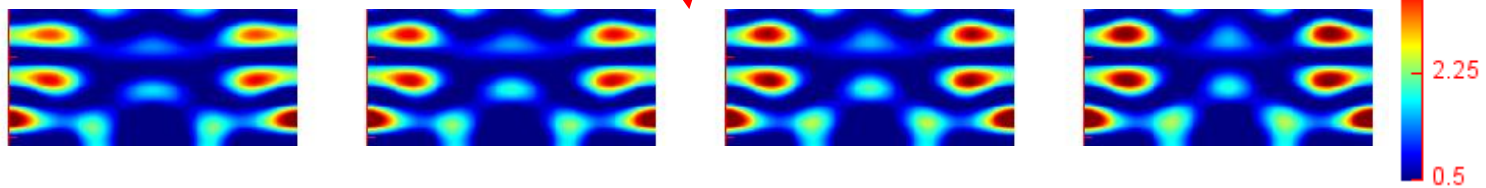


Impacts from Residual SiO_2 Layers from CMP

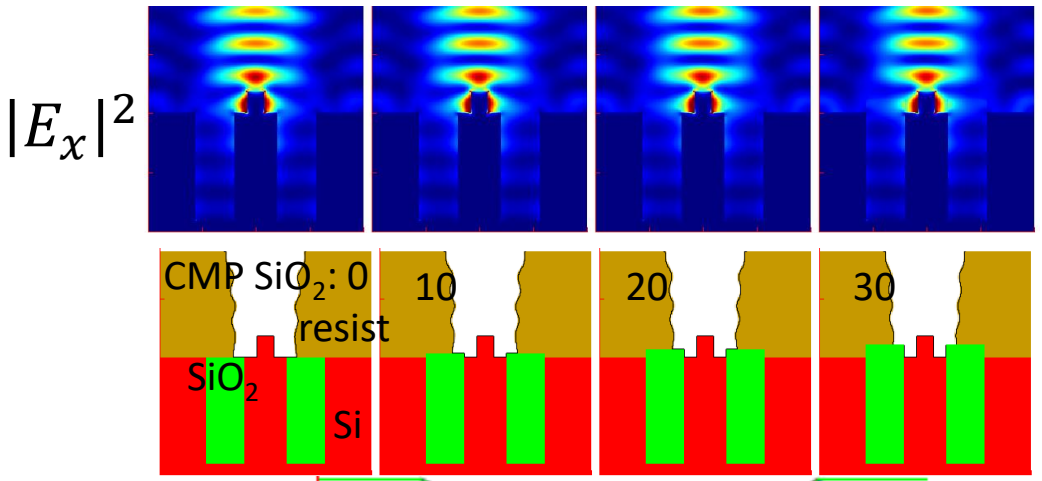
varying residual SiO2 thickness from 0 to 30 nm

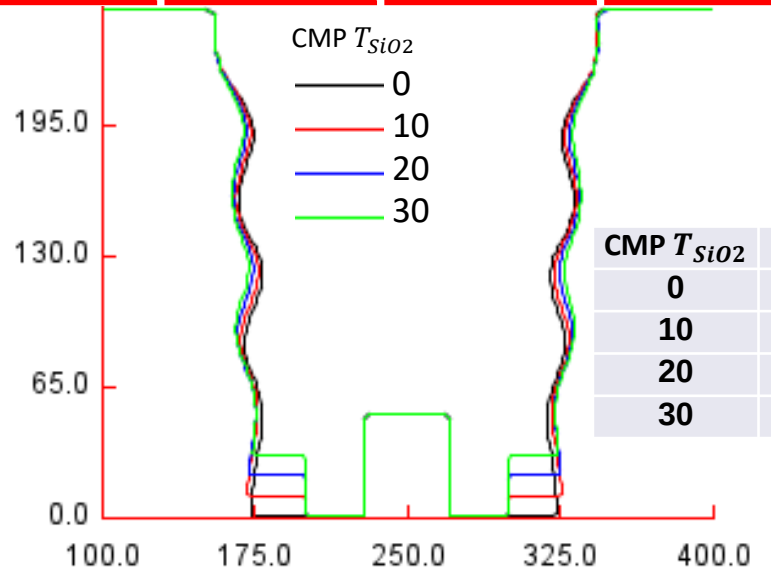
Light is affected less by the CMP residual SiO_2, particularly X-plarization





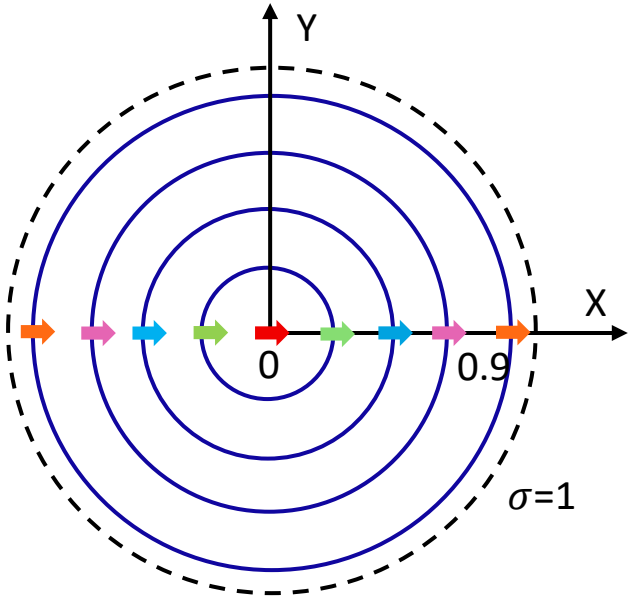
with Mask

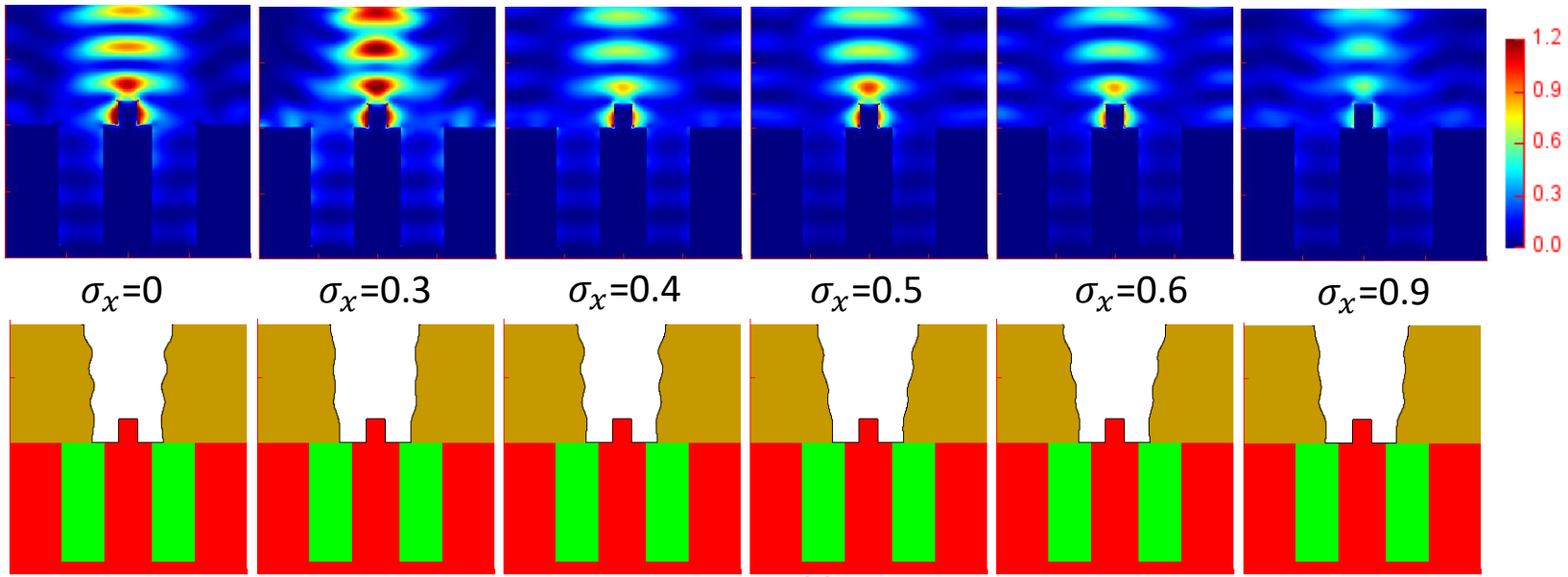




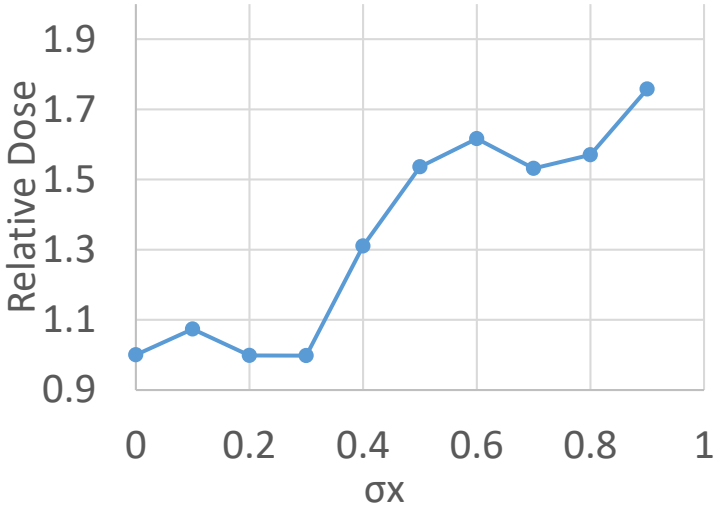
CMP T_{SiO2}	PPE
0	0
10	0.8
20	0.9
30	-0.4

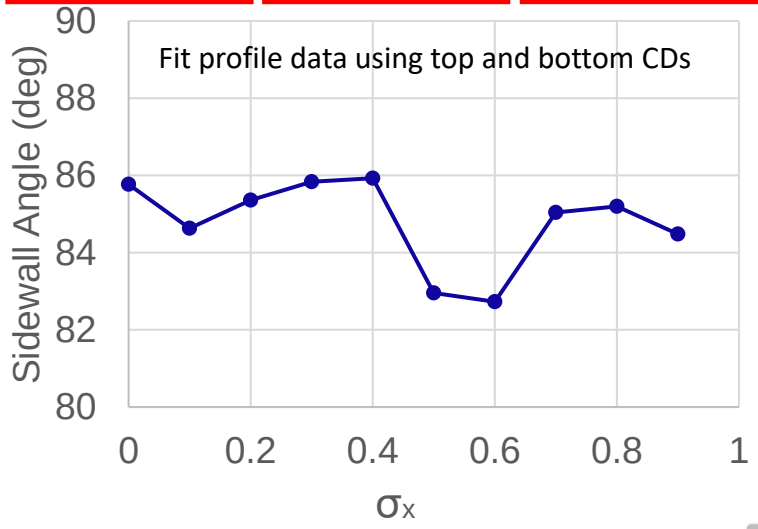
Off-Axis E_x Planar Wave Illumination





- The larger off-axis sigma, less gate surface reflection
- Sidewall angle varies more at σ ~0.5 to 0.6
- Sidewall resonance varies regarding σ due to corner and interface reflections



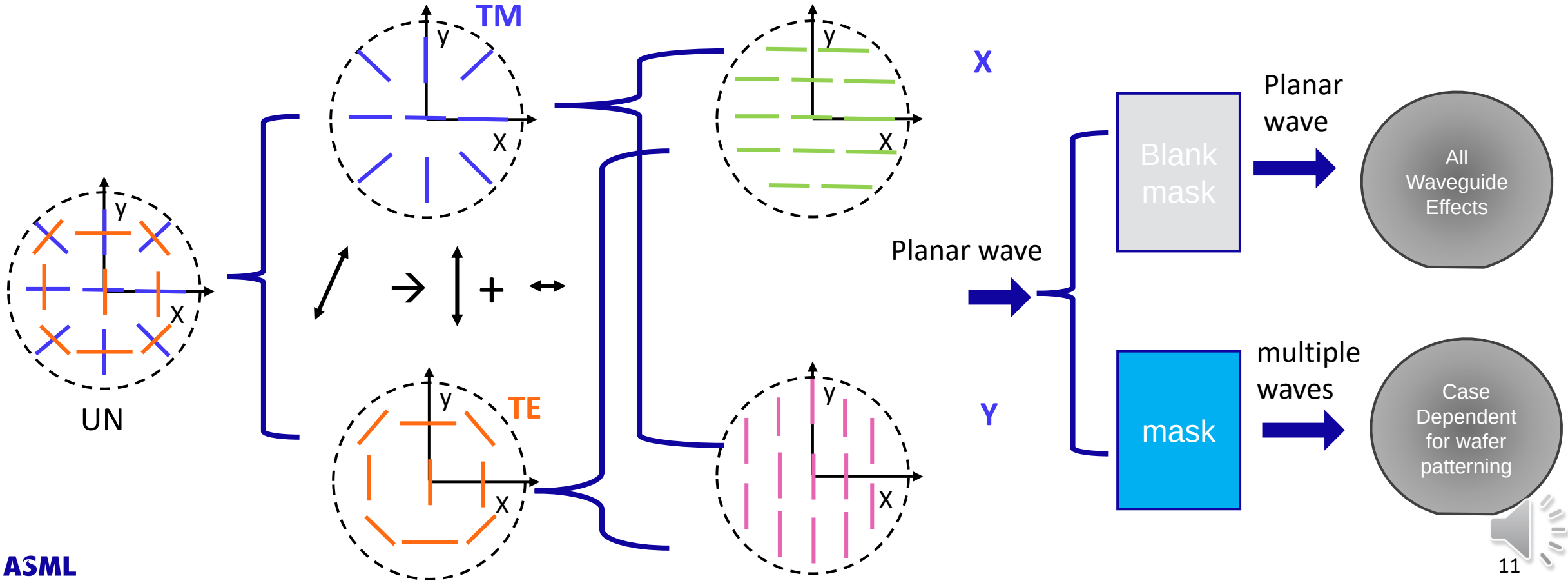


How do we correlate E_x or E_y to commonly used polarizations?

Pupil Illumination

Polarization Decomposition Scheme

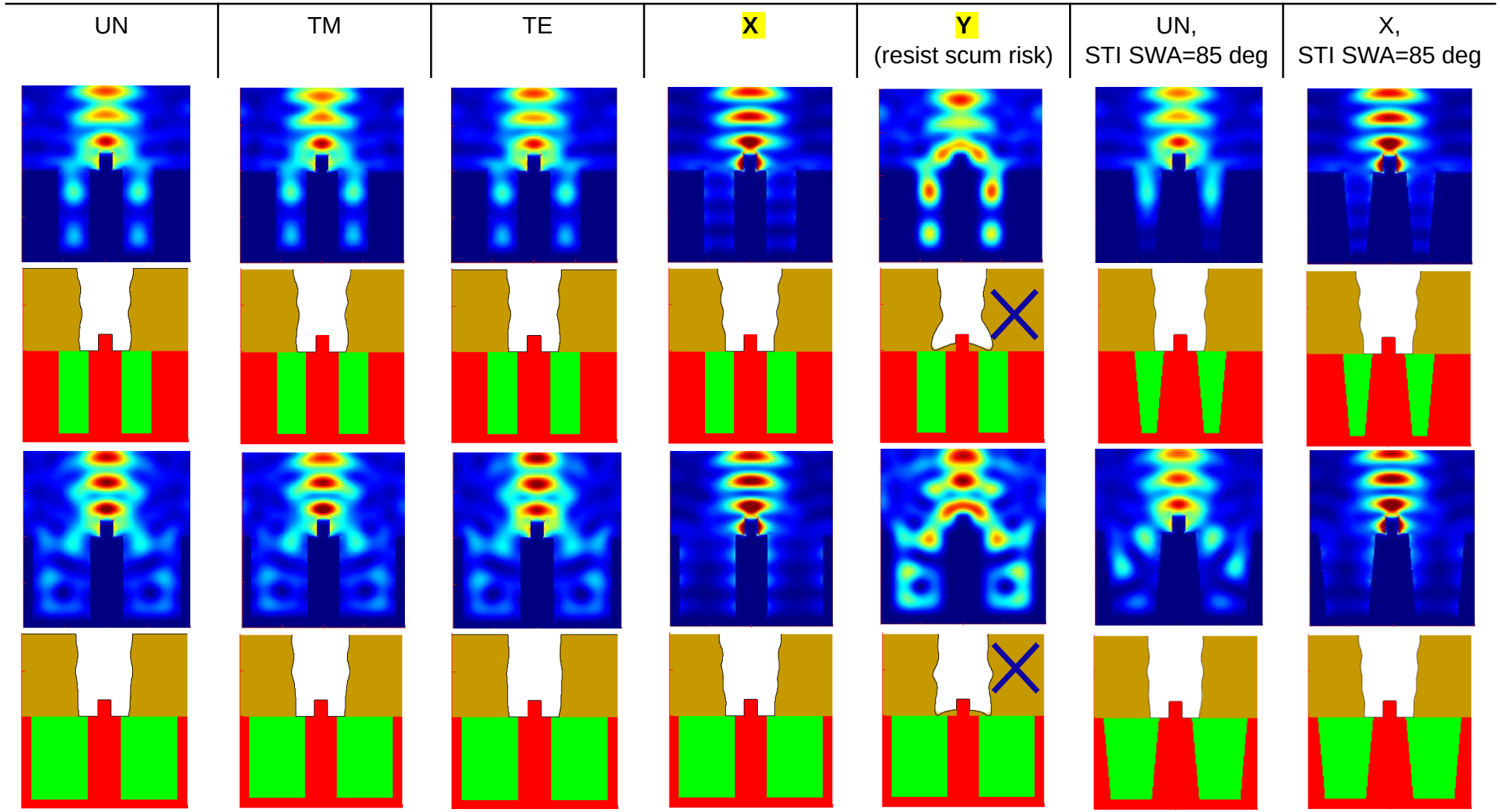
- X-, and Y- polarized light (linearly polarized) are the basis for complex polarizations
- Single planar wave illumination remain planar wave projection onto wave with blank mask.
- Single planar wave is always scattered and diffracted by the pattern → multiple waves project to wafer, could have similar patterning results, here, i.e., the resist profiles.



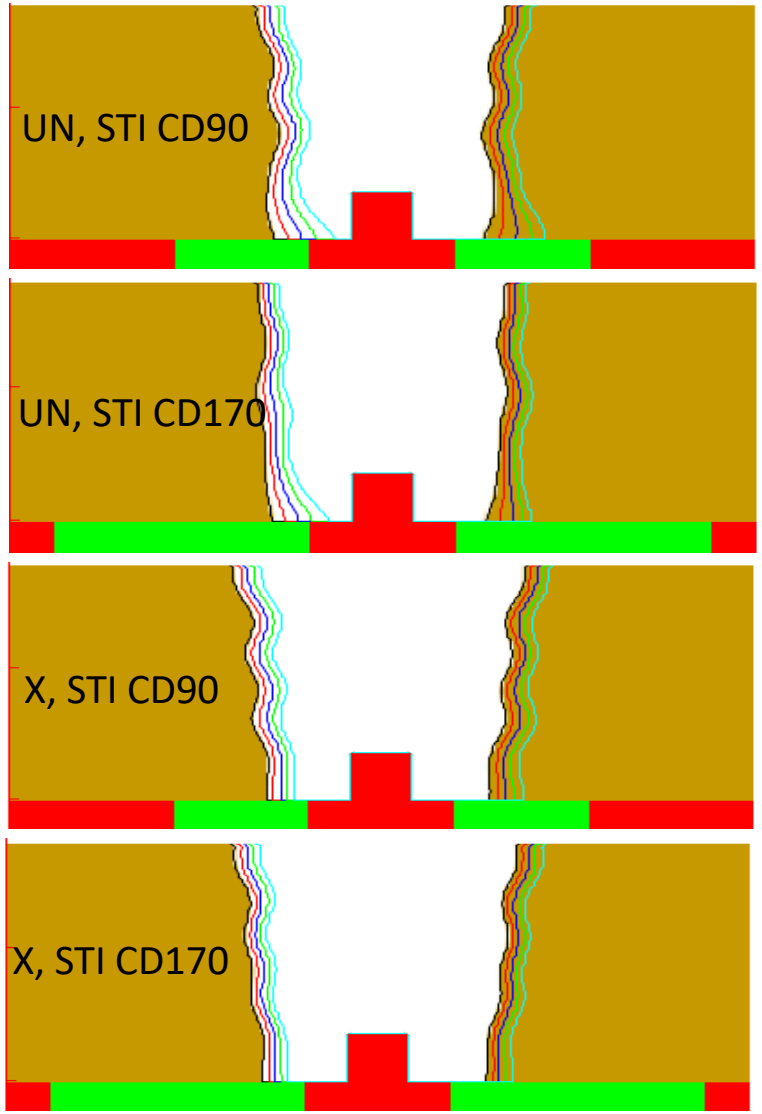
Conventional Pupil Illumination

UN, TM, TE-polarizations have similar performance due to Y-polarization contribution.
Slight profile tuning is available by optimizing STI geometries, e.g., STI sidewall angle.

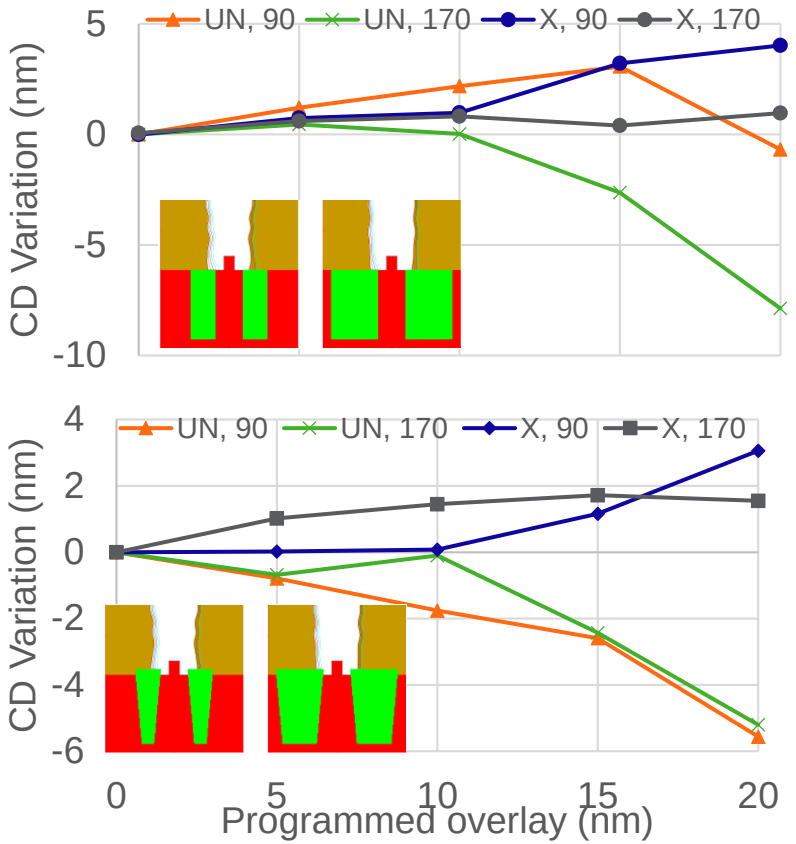
NA=0.8,
σ=0.5,
248 nm

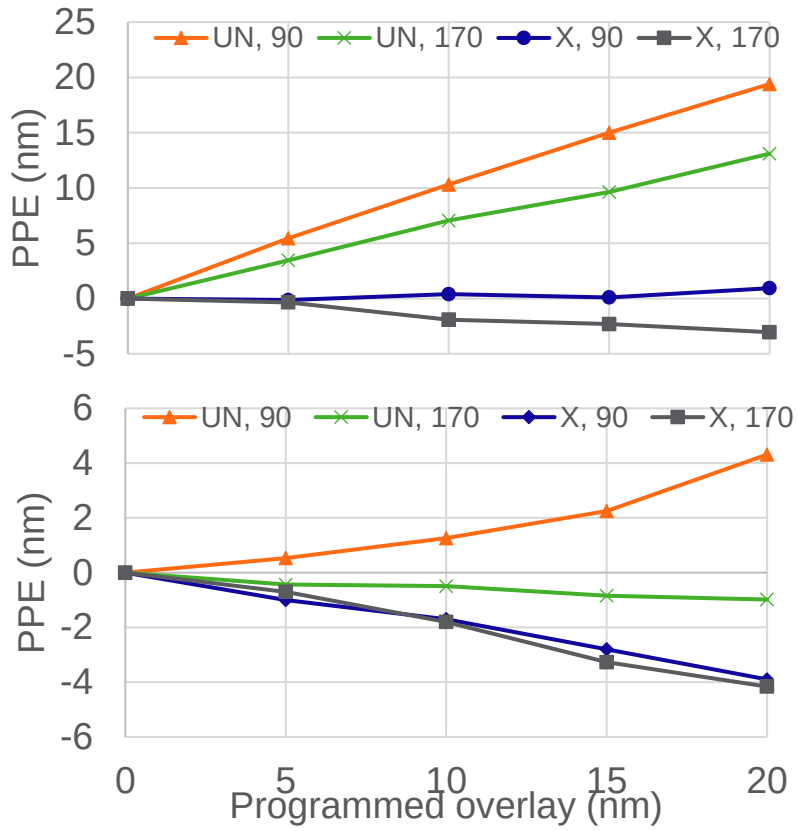


Profiles Stability Regarding Overlay Impact



E.g., with 90° STI elements due to page limit.



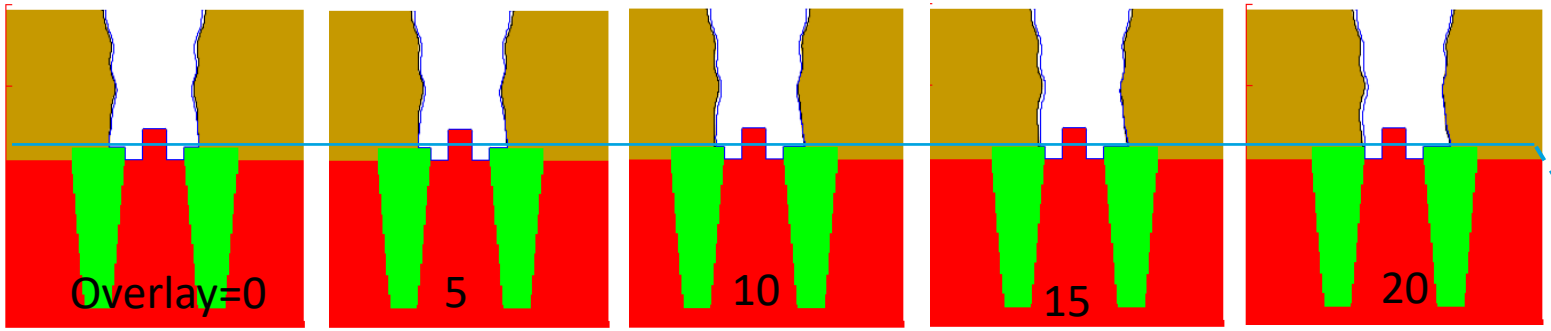


- Resist profile under x-polarized light is more stable than un-polarized
- Impact of topography geometries on X-polarized light is small
- Placement error for un-polarized light can be modified by STI geometry, to reduce influence from Y-polarized wave components

CD and PPE are measured at the bottom of resist

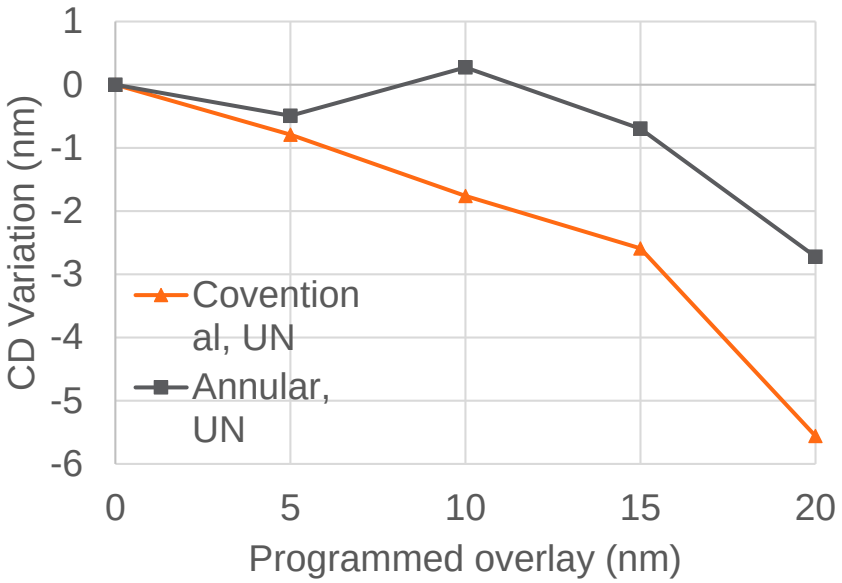
Topography Impact on Imaging a Different Pupil

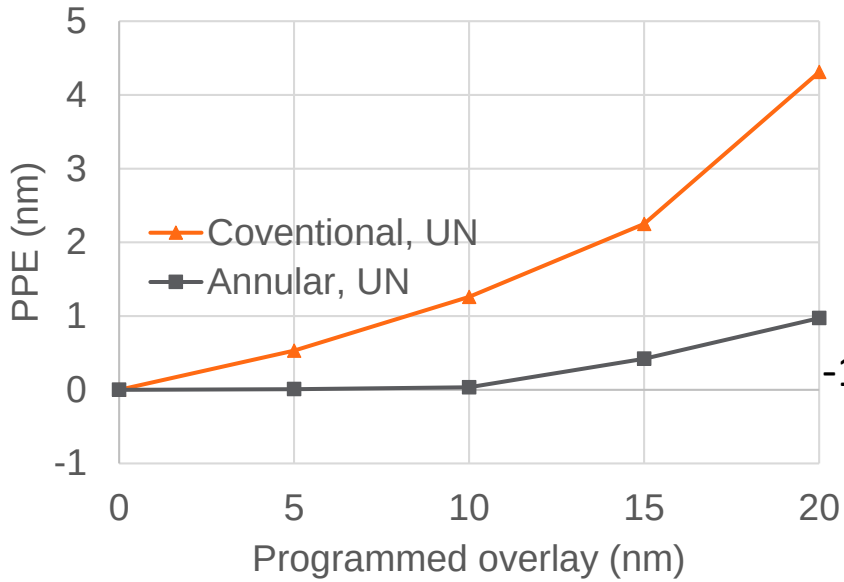
CD tolerance to overlay error can be improved by properly selected pupil

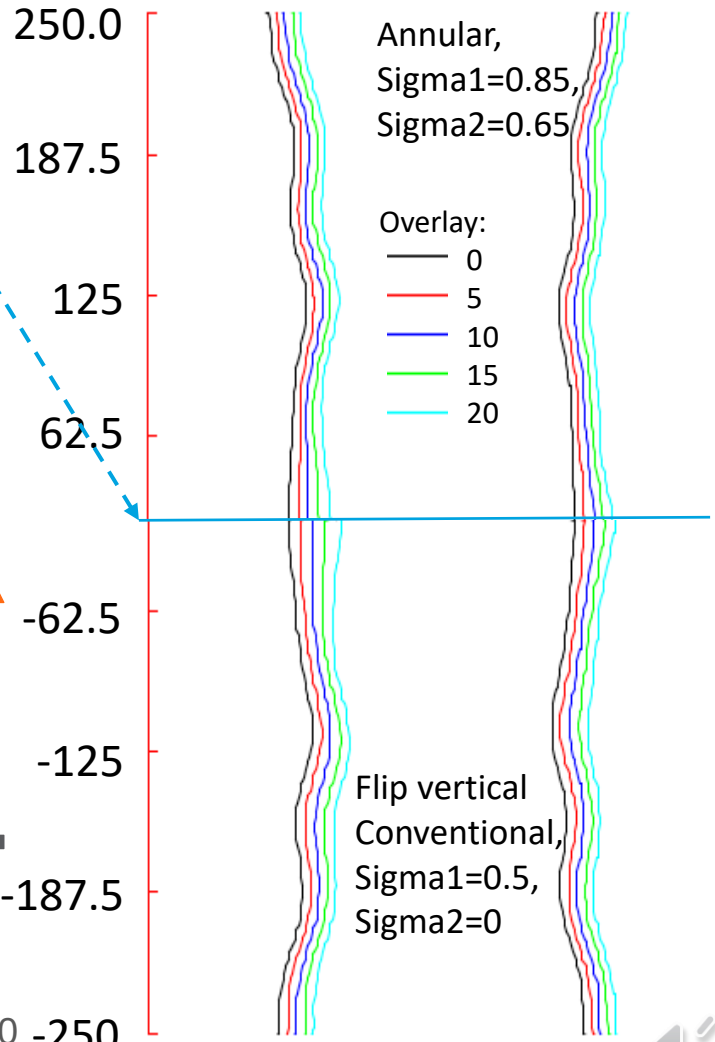


Annular,Sigma1=0.85, Sigma2=0.65.

Edge contour left: Black-annular; Blue-conventional;

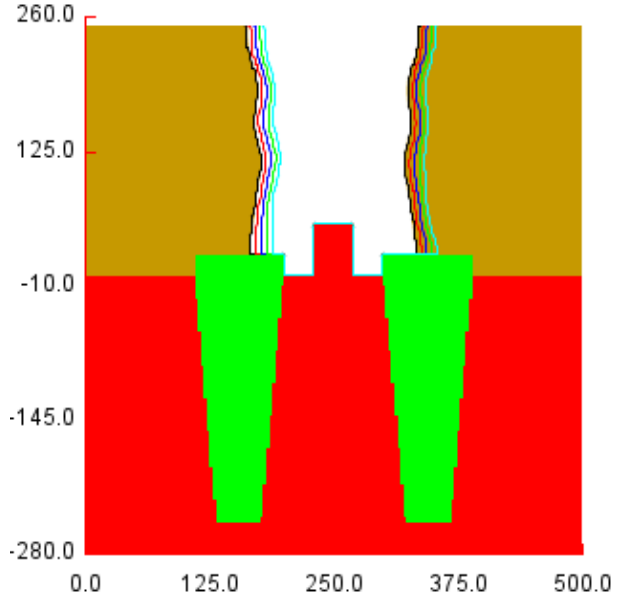




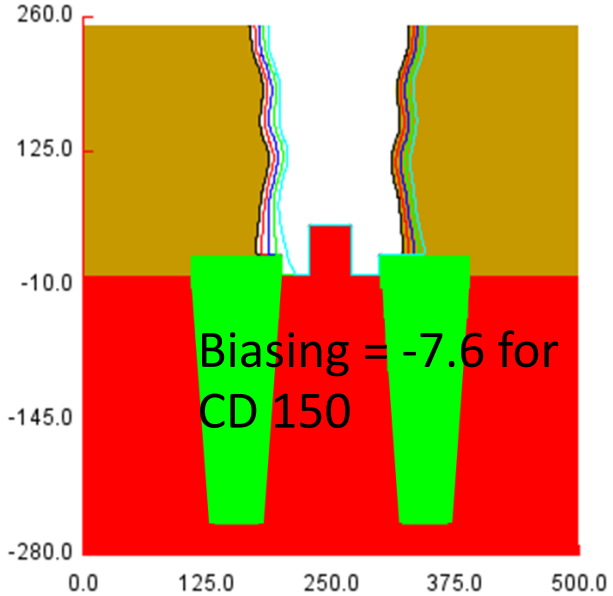


Mask Correction for Topography Effect

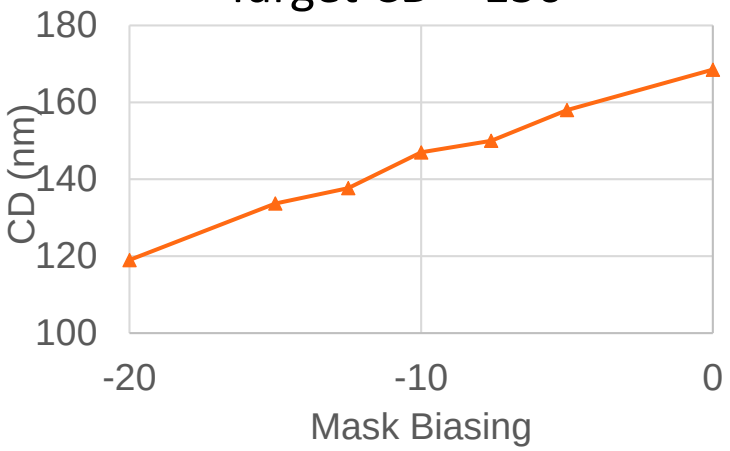
Mask CD = 150

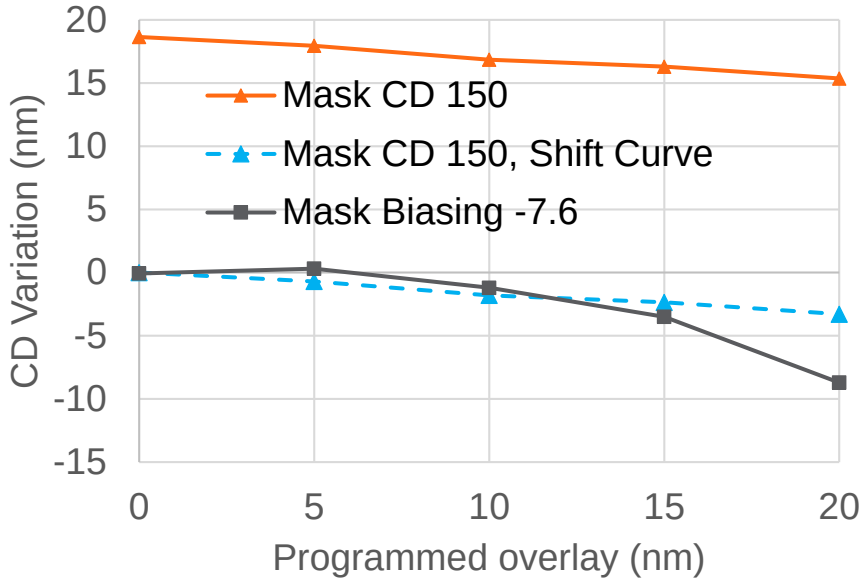


Corrected Mask CD =142.4

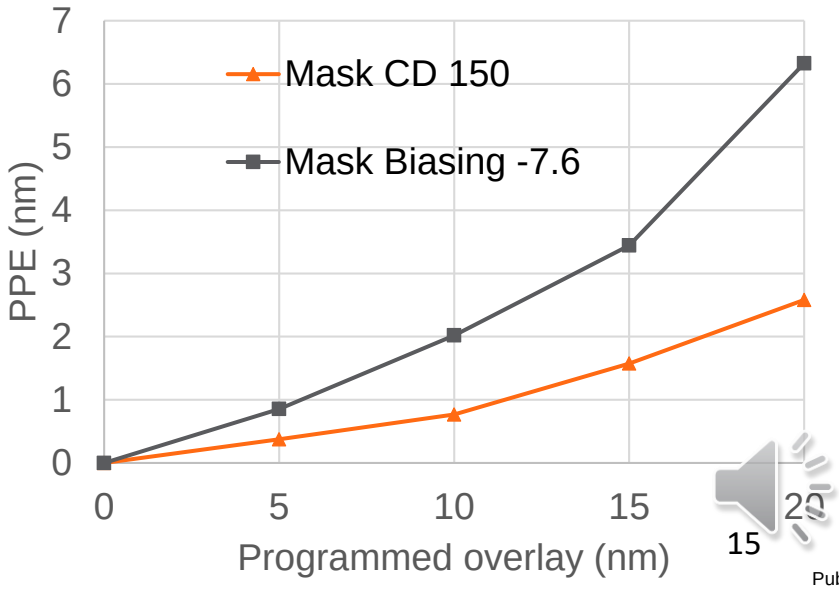


CD measured at top of CMP SiO_2
Target CD = 150





PPE becomes worse



Summary

- Planar wave illumination analysis enables to understand the imaging impact of STI mode and its sensitivities.
- X- and Y-polarized light interact very differently in wafer topography effect and at pre- and postgate cases.
- Imaging simulation and analysis are carried out to understand how wafer topography affects the resist edges and CD.
  - Polarizations
  - Geometries
  - Overlays
  - Pupil Shapes
  - Mask biasing for CD on-target.
- Future work could extend the study to FinFET implantation, and topography aware imaging optimization for DUV and EUV topics.