Metal Oxide EUV Photoresists for N7 Relevant Patterns

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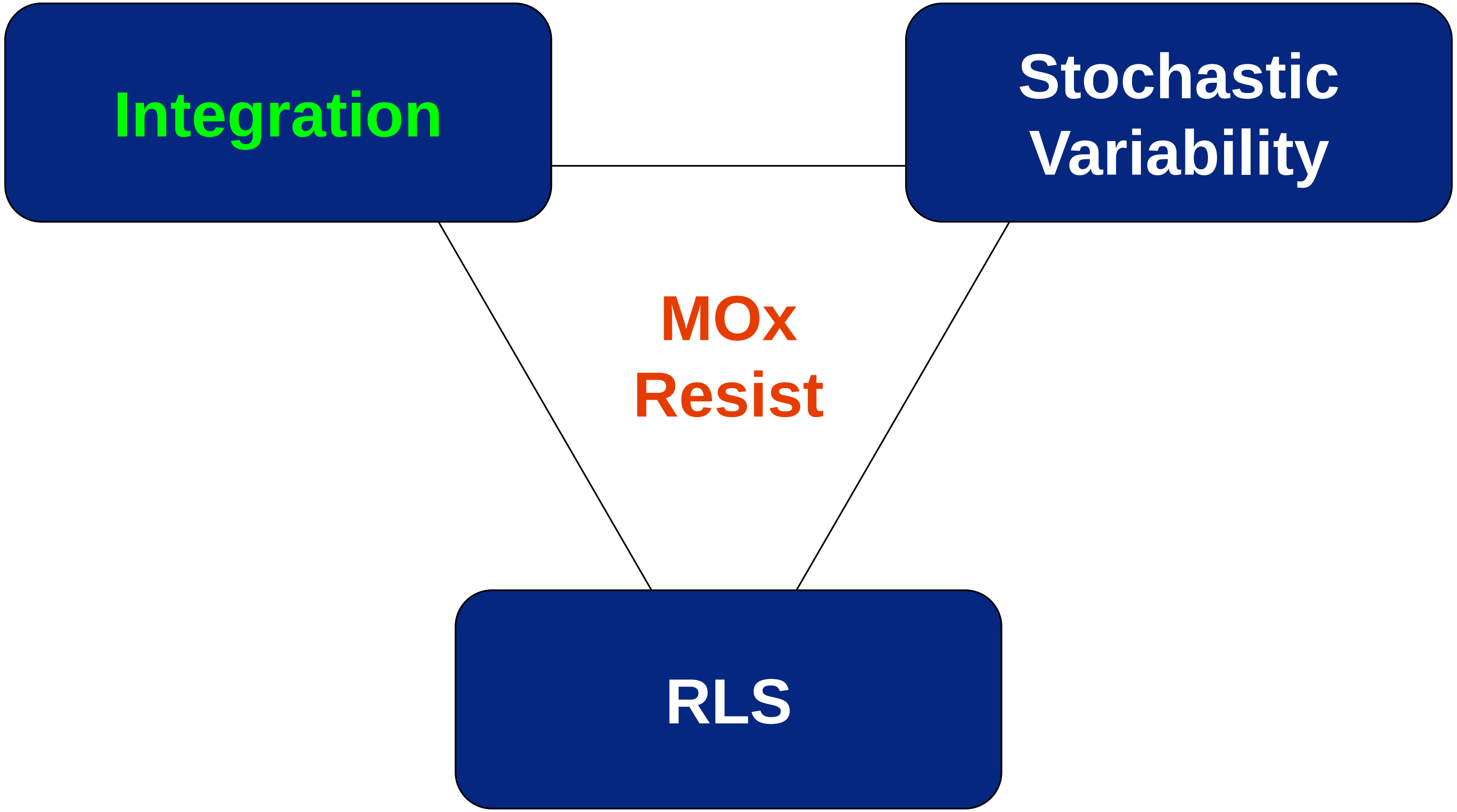
inpria

2016 International Workshop on EUV Lithography

Resists Designed for EUV Lithography



Baseline MOx Resist Platform

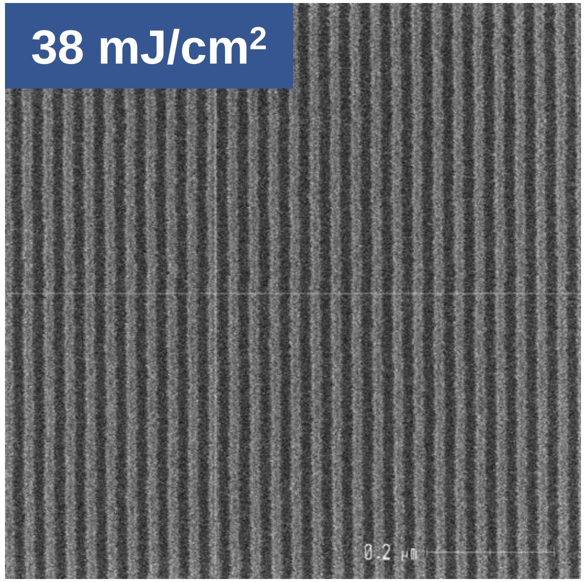
- SnO_x based resist
- E_{size} @ 16nm HP: ~37 mJ/cm^2
  - EL_{max}: 29%
  - Resist thickness ~18nm

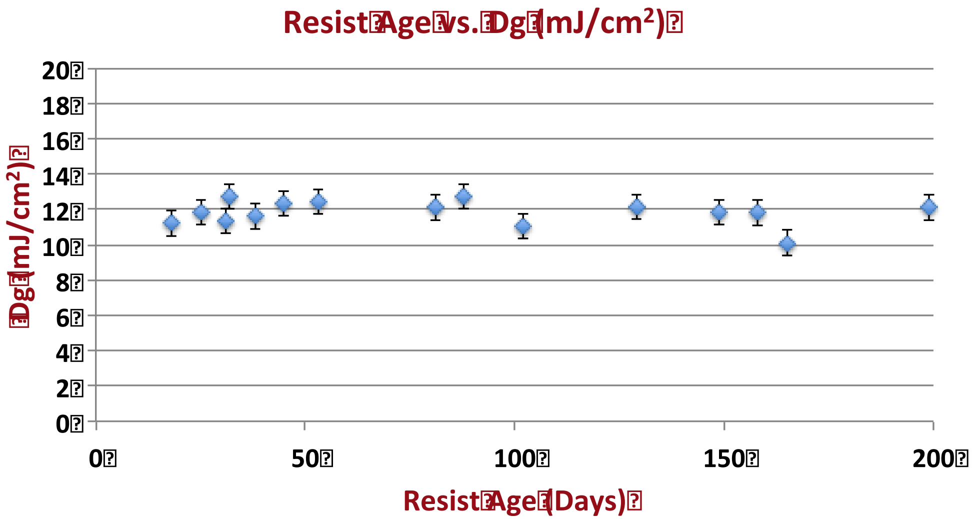
- Formulation scaled to multi-gallon batches, installed on multiple tracks/fabs enabling critical learning:
  - Track Compatibility
  - Stability
  - Filtration
  - Defectivity
  - CDSEM Metrology
  - OPC / Litho modeling

16L32P

CD = 16.3 nm
LWR = 3.8 nm

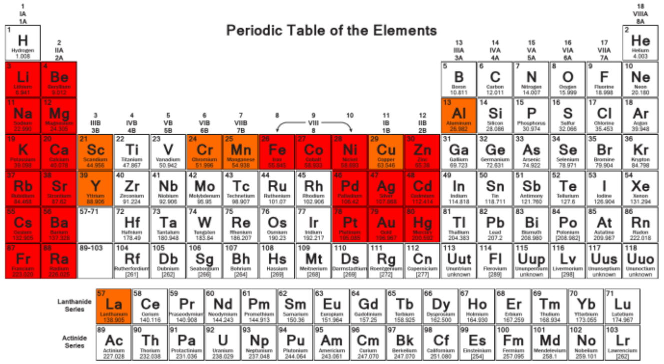
NXE:3300
dip90Y





MOx Resists Fab Acceptance

- Matrix Metal: Sn
  - Track / Etch Cross Contamination
  - EUV Outgassing

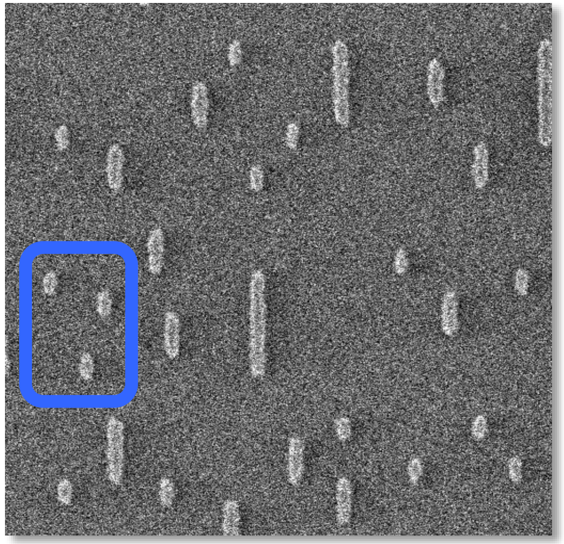


All tested trace metals < 10 ppb

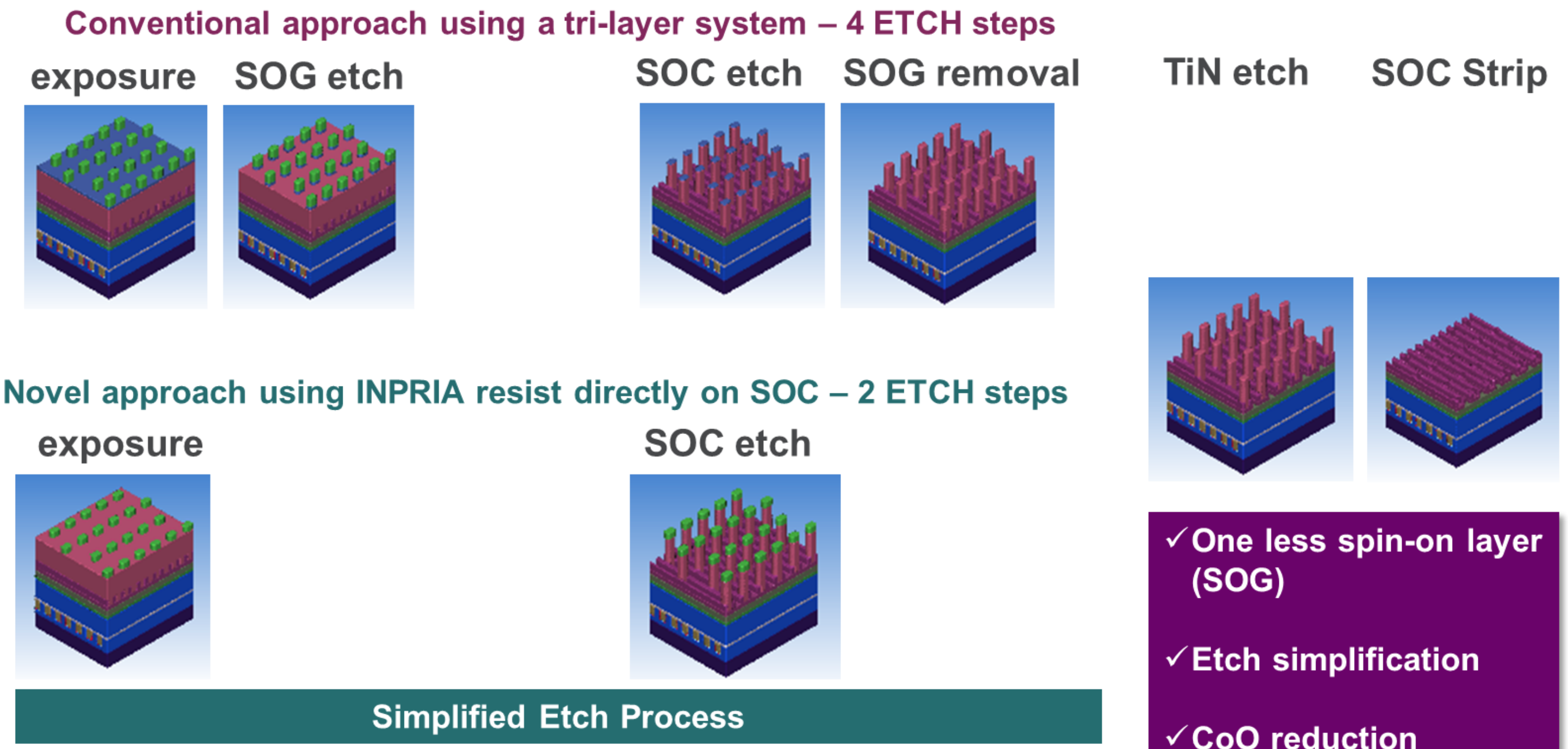
Formulation:	YF-Series					
Batch:	Batch #1		Batch #2		Batch #3	
Element	ppb	ppb	ppb	ppb	ppb	ppb
Ag	<10	<10	<10	<10	<10	<10
Al	<10	<10	<10	<10	<10	<10
As	<10	<10	<10	<10	<10	<10
Au	<10	<10	<10	<10	<10	<10
Ba	<10	<10	<10	<10	<10	<10
Ca	<10	<10	<10	<10	<10	<10
Cd	<10	<10	<10	<10	<10	<10
Co	<10	<10	<10	<10	<10	<10
Cr	<10	<10	<10	<10	<10	<10
Cu	<10	<10	<10	<10	<10	<10
Fe	<10	<10	<10	<10	<10	<10
K	<10	<10	<10	<10	<10	<10
Li	<10	<10	<10	<10	<10	<10
Mg	<10	<10	<10	<10	<10	<10
Mn	<10	<10	<10	<10	<10	<10
Na	<10	<10	<10	<10	<10	<10
Ni	<10	<10	<10	<10	<10	<10
Pd	<10	<10	<10	<10	<10	<10
Sn	matrix	matrix	matrix	matrix	matrix	matrix
Ti	<10	<10	<10	<10	<10	<10
V	<10	<10	<10	<10	<10	<10
W	<10	<10	<10	<10	<10	<10
Zn	<10	<10	<10	<10	<10	<10

- Trace Metal Impurities
  - Developed ICP-MS methods to eliminate mass interferences from Sn
    - Enabling Lower Detection Limits
    - Example: isotope overlap between ^{112}Sn and ^{112}Cd
  - Demonstrated multiple large batches with no detectable trace metals

MOx Resist Integration: IMEC iN7 Metal 2 Block Layer



- CD-X Target 21nm ± 10%
- Dose to size: 49mJ/cm^2
- Customized illumination
- El_{max}:22%, DOF @ 10%EL:118 nm
- X-Wafer CDU 3σ: 1.8nm



- ✓ One less spin-on layer (SOG)
- ✓ Etch simplification
- ✓ CoO reduction

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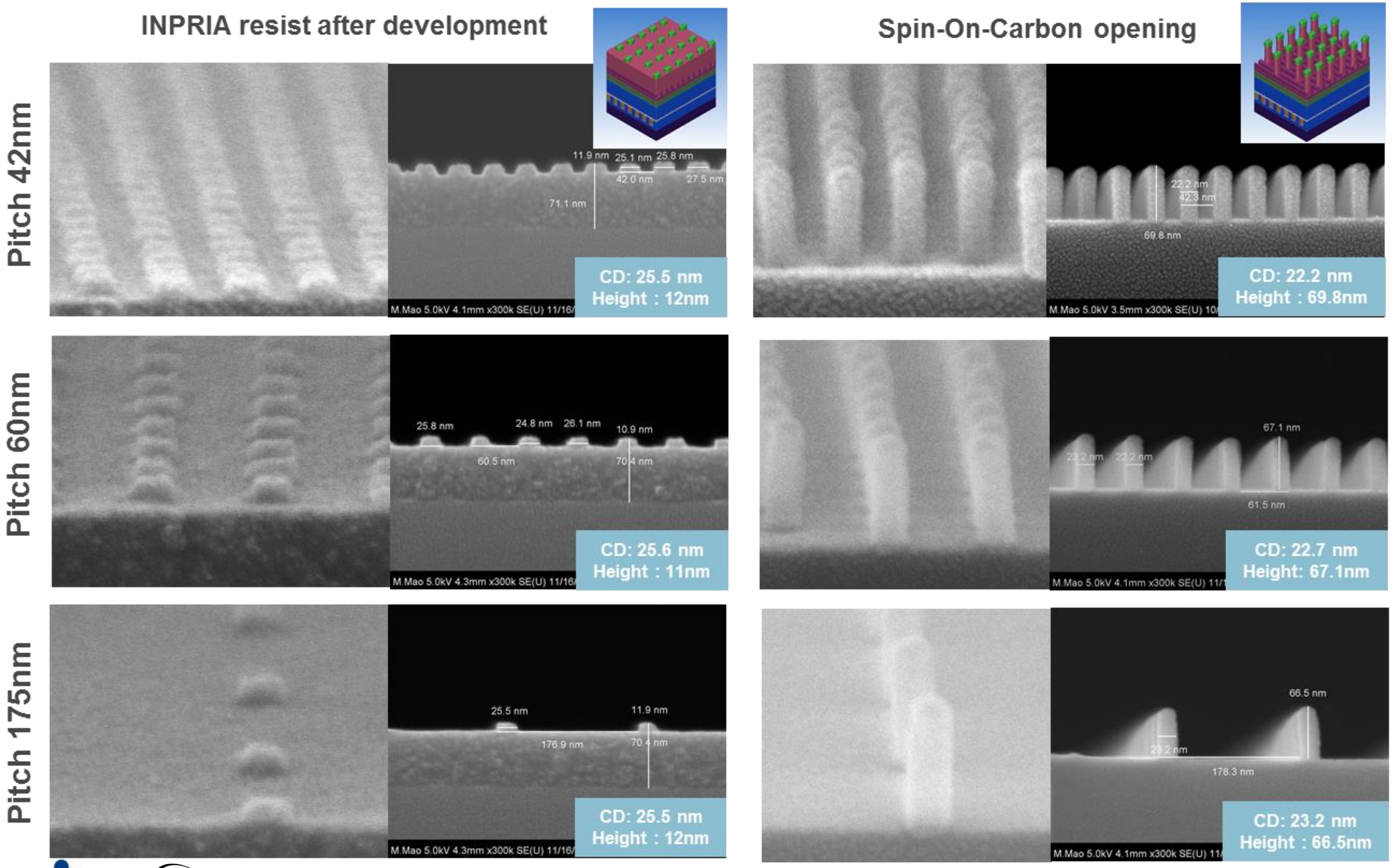
De Simone, D. et al. Proc. SPIE, 9776-11 (2016)

MOx Resist Integration: IMEC iN7 Metal 2 Block Layer



- High Resist-SOC etch selectivity
- Straight SOC pillar profile
- Constant litho-etch CD bias through pitch for these structures

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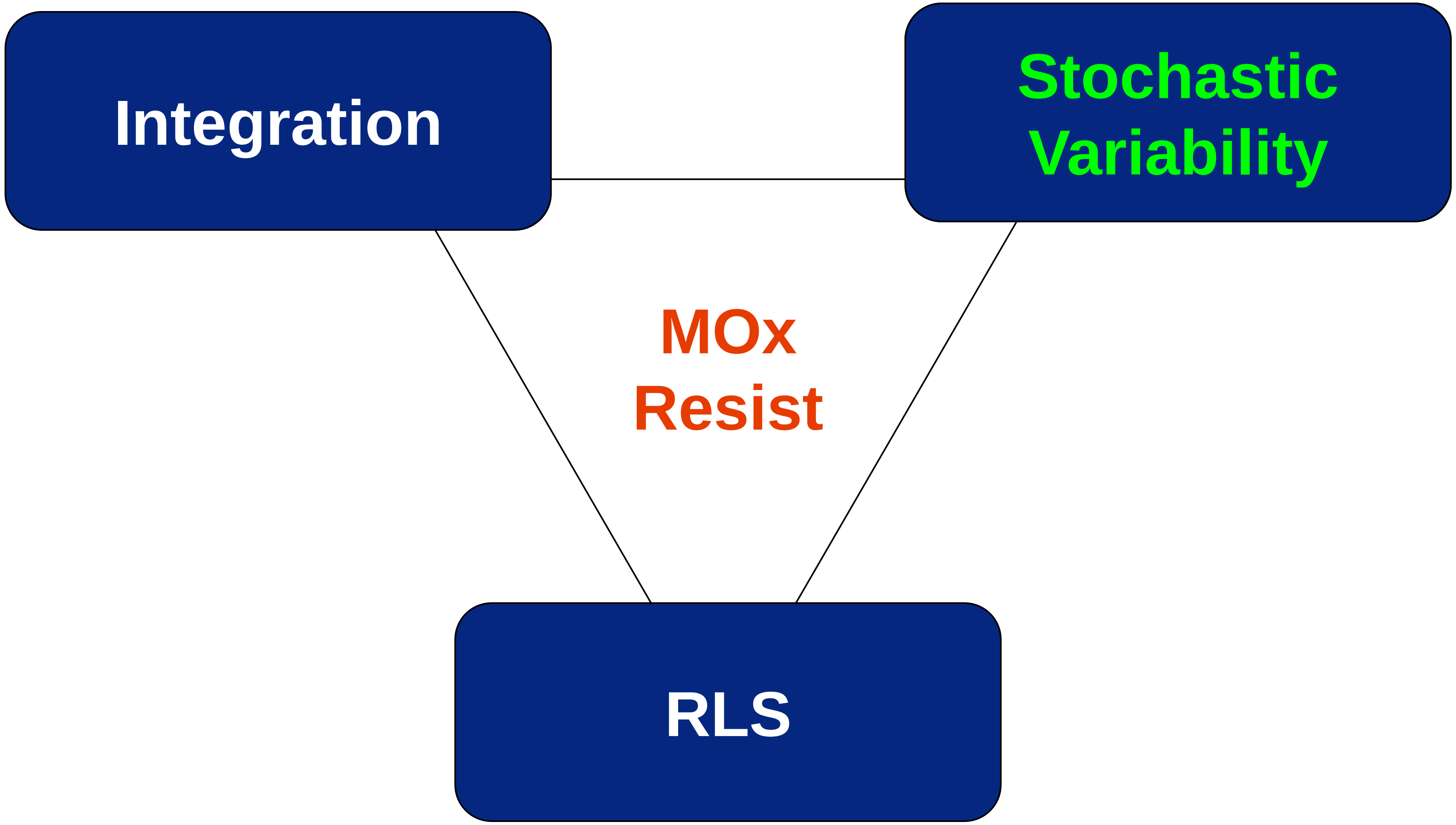
Resists Designed for EUV Lithography

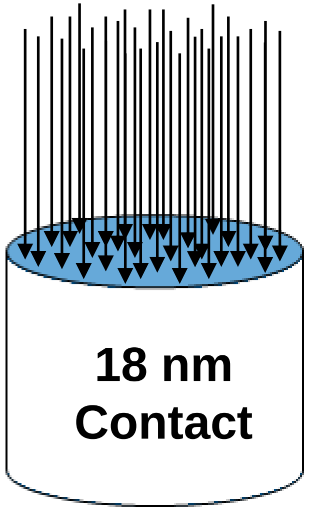


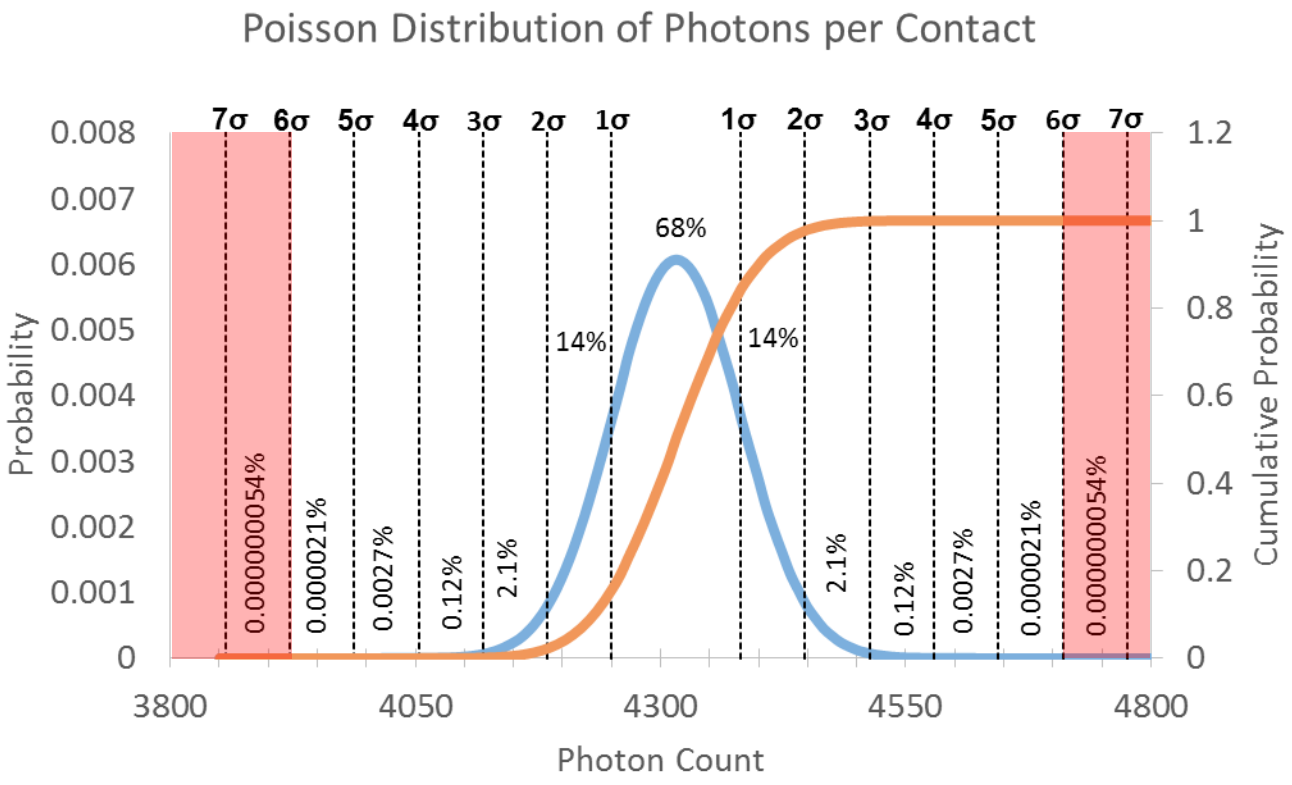
EUV Photon Shot Noise

- Consider contacts/pillars
- Photon shot noise → dose fluctuation from contact to contact
- Billions of contacts per die: need to consider 7σ variation

Photon Density

25 mJ/cm²

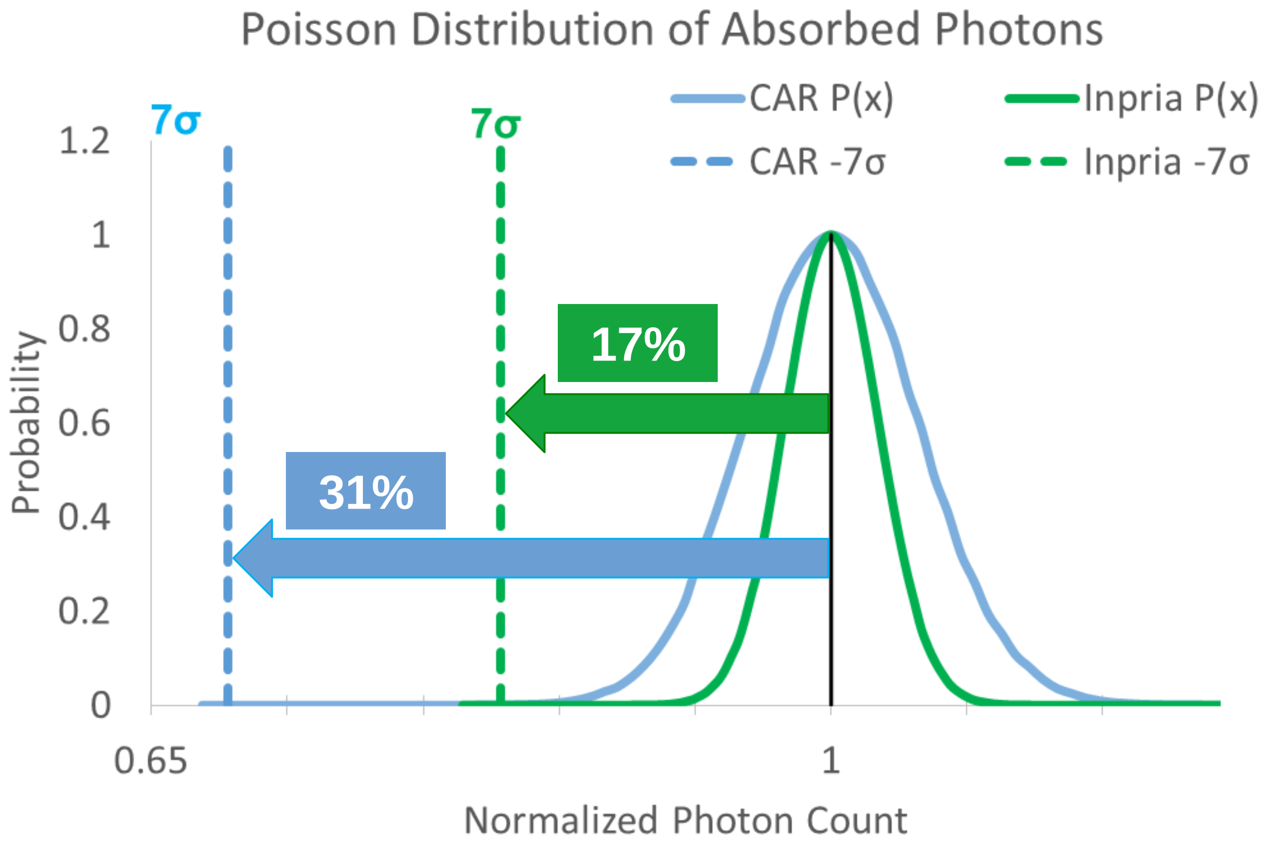




Absorbed Photon Shot Noise

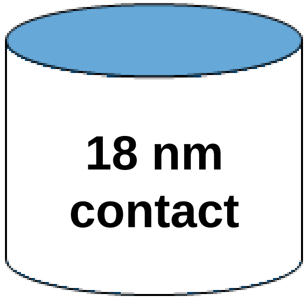
- Variation in effective dose due to statistical distribution of absorbed photons
- When too few absorbed, contact/pillar will not form
- Exposure latitude of resist process must accommodate this variation

Resist	Absorbance (1/μm)	Thickness (nm)
Inpria	20	25
CAR	5	25



Fallica, R. et, al. Proc. SPIE, 9776-39 (2016)

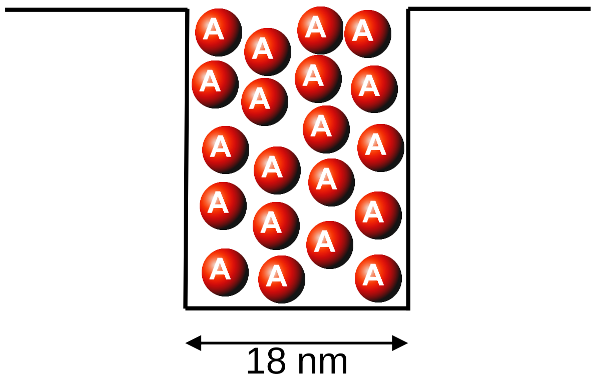
Stochastic Material Composition: CAR



= 2036 PAGs, 407 Quencher

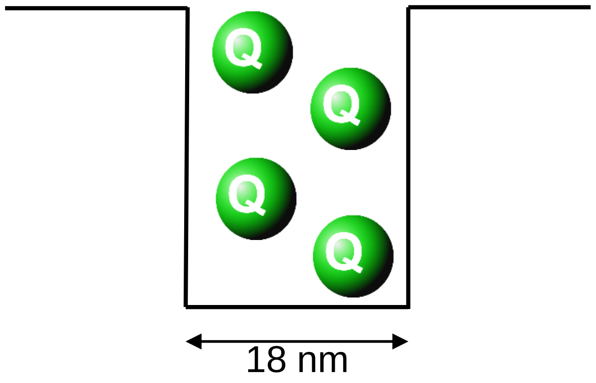
PAG = A

Quencher = Q



± 16% PAG

At 7σ



± 35% Quencher

Assume: 40 nm FT, 0.2 PAG/nm^3, 0.04 Quencher/nm^3

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Stochastic Material Comparison

- Inpria materials have lower initial stochastic variability
  - No minor components
  - Small, uniform building blocks (~1.4 nm dia)
  - High concentration of bound photoactive centers
- Higher Homogeneity

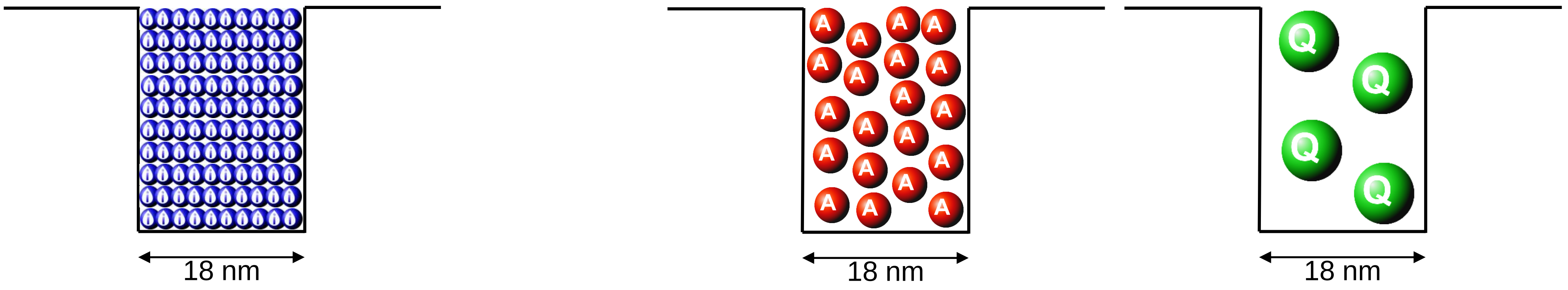
PAG = A

Quencher = Q

Inpria MOx units= i

Inpria MOx

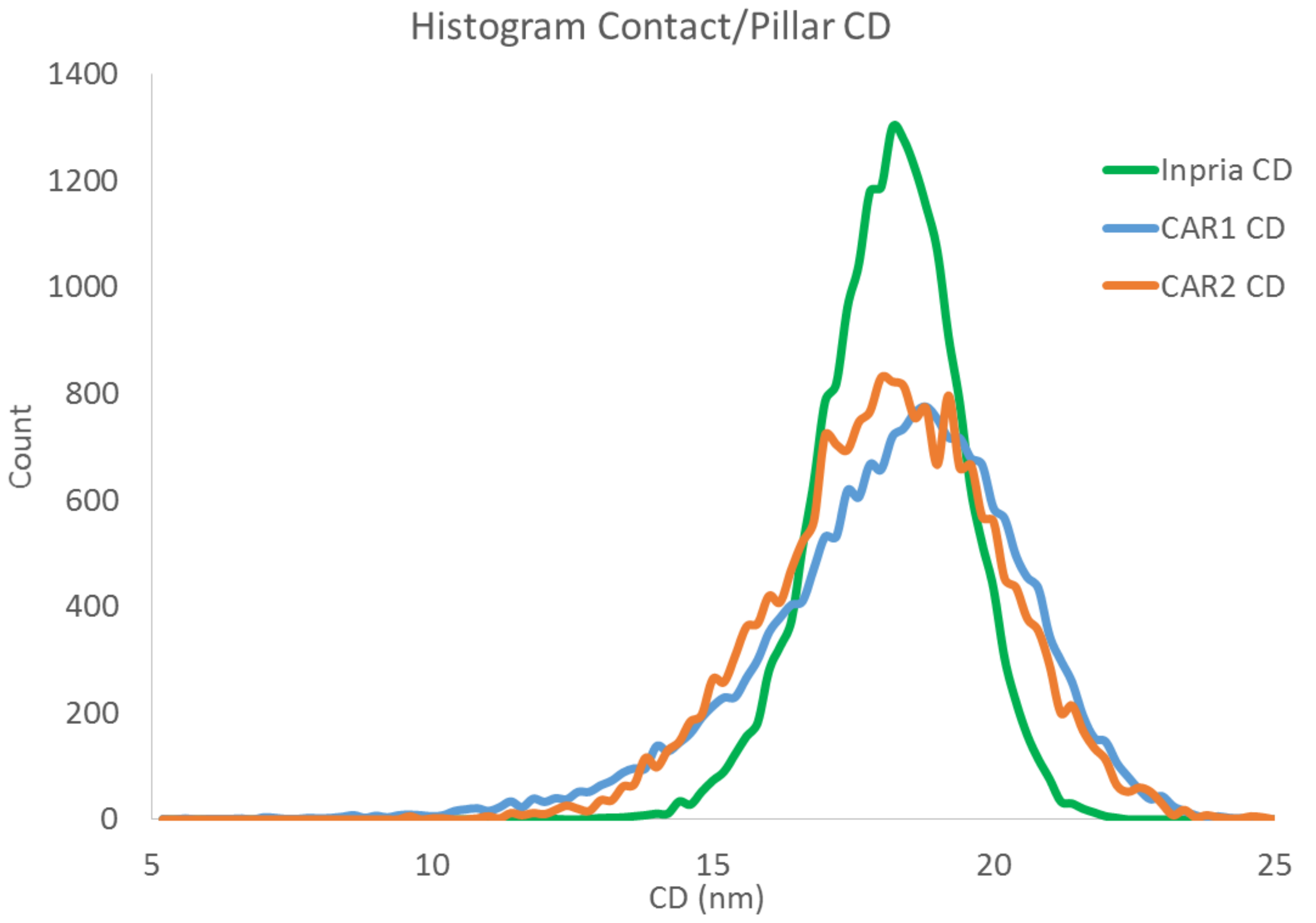
CAR



Resist Modeling

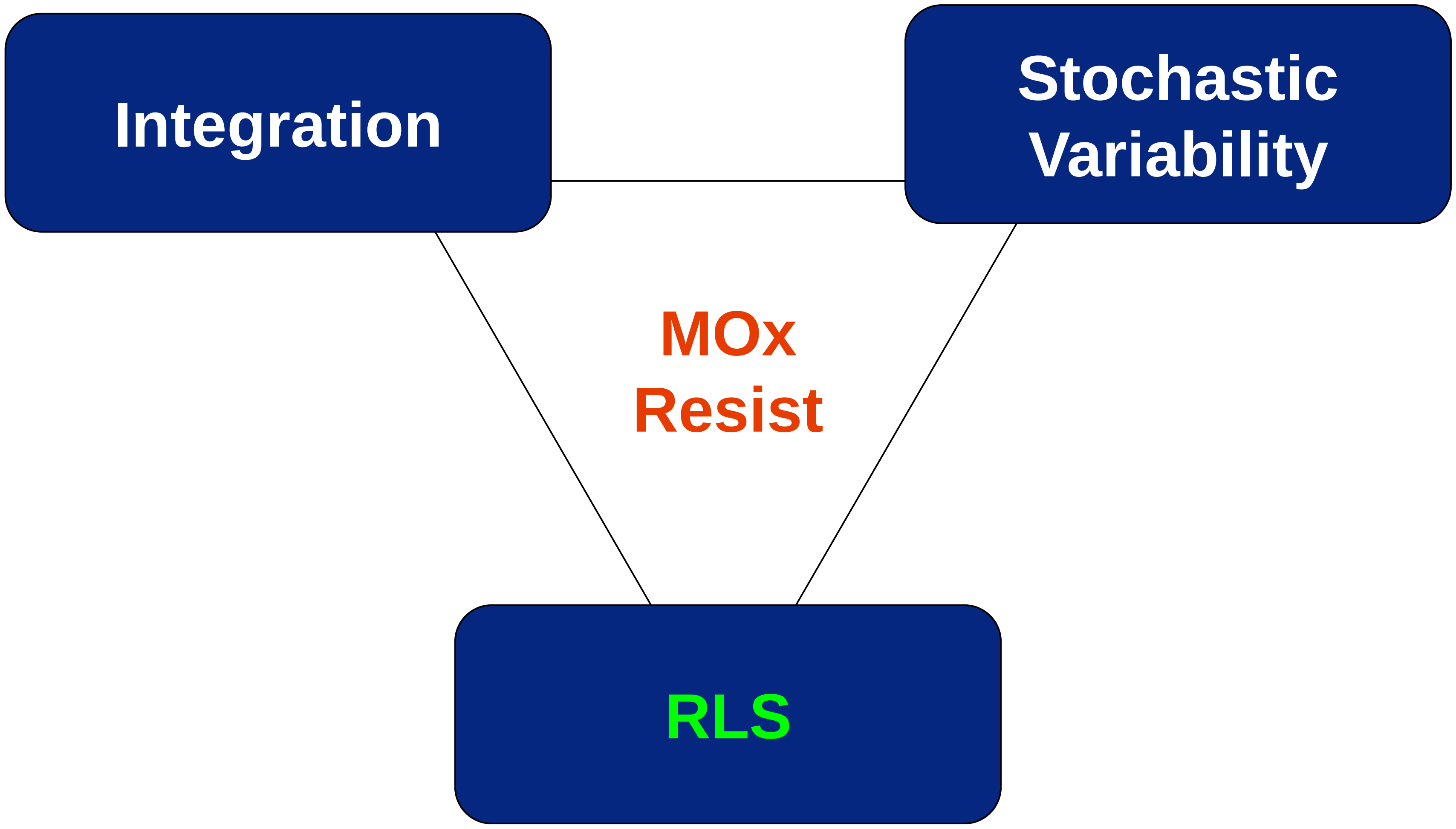
- Initial Inpria resist model created using PROLITH™
  - Based on physical measurements and CDSEM of pillars & lines
  - Baseline resist
- 20,000 contacts simulated
  - 18P36, NA 0.33, Quad30

Resist	Thickness (nm)	Dose (mJ/cm^2)
Inpria	18	40
CAR1	40	36
CAR2	40	52

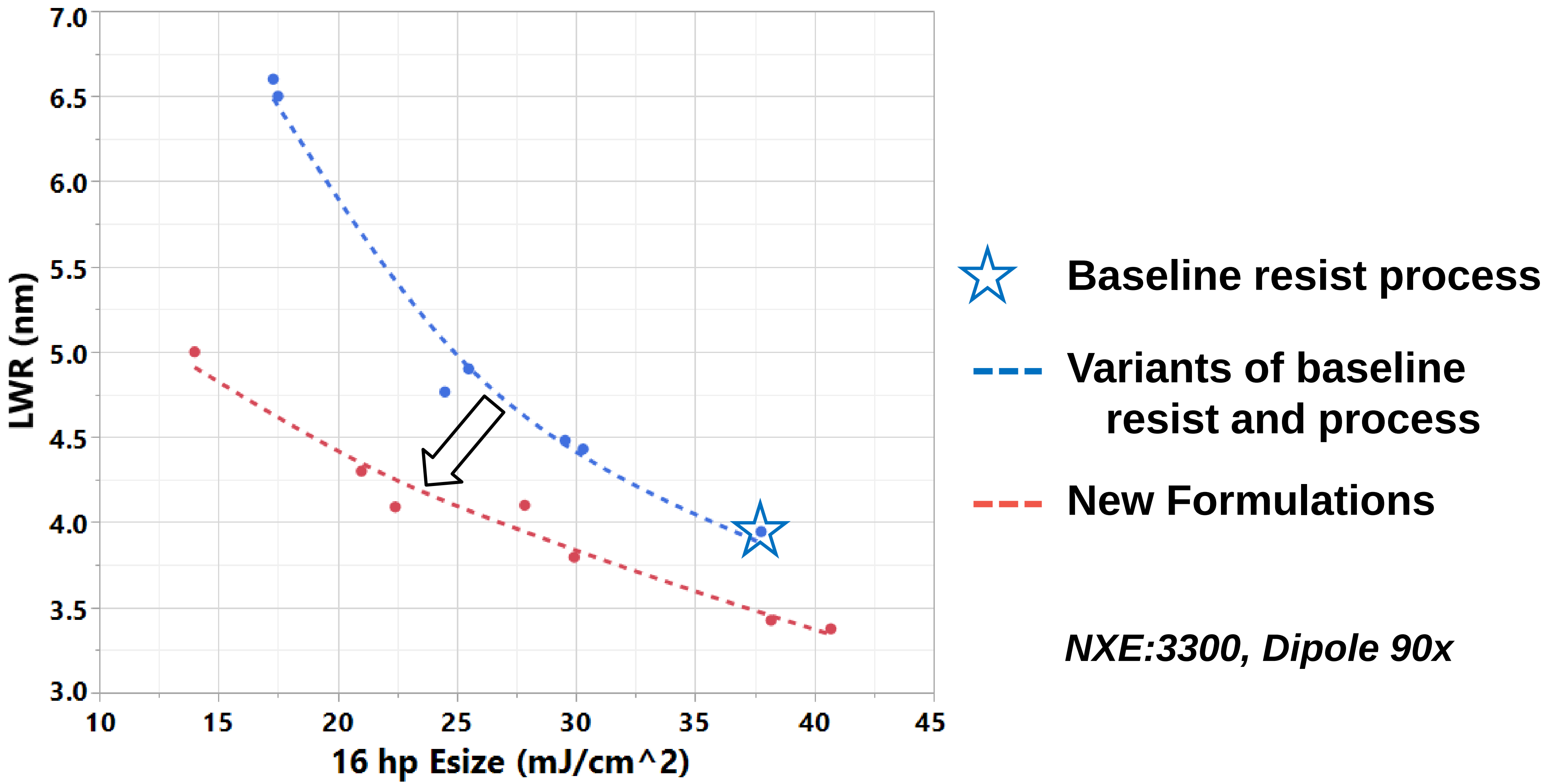


Vaglio Pret, A. et al. Proc. SPIE, 9779-06 (2016)

Resists Designed for EUV Lithography



Resist Performance Improvements Toward N7 Targets

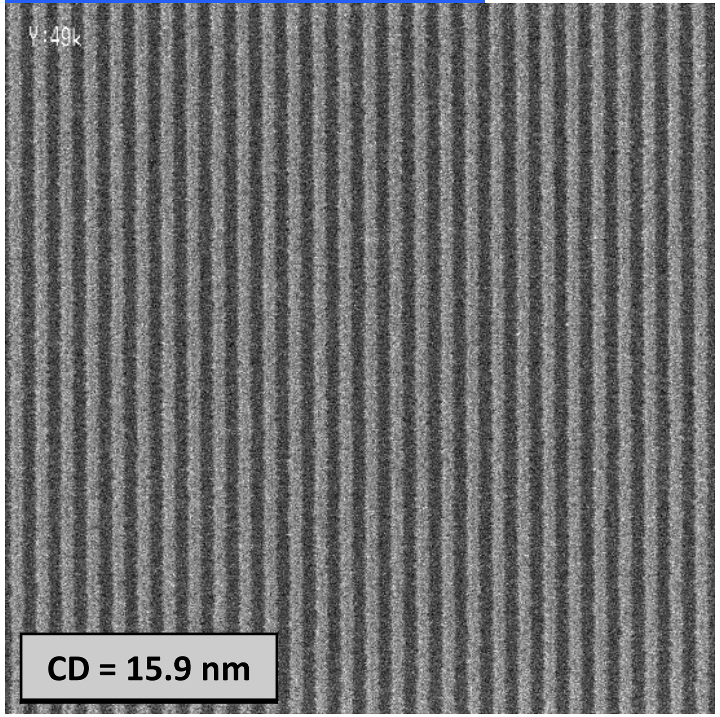


NXE:3300, Dipole 90x

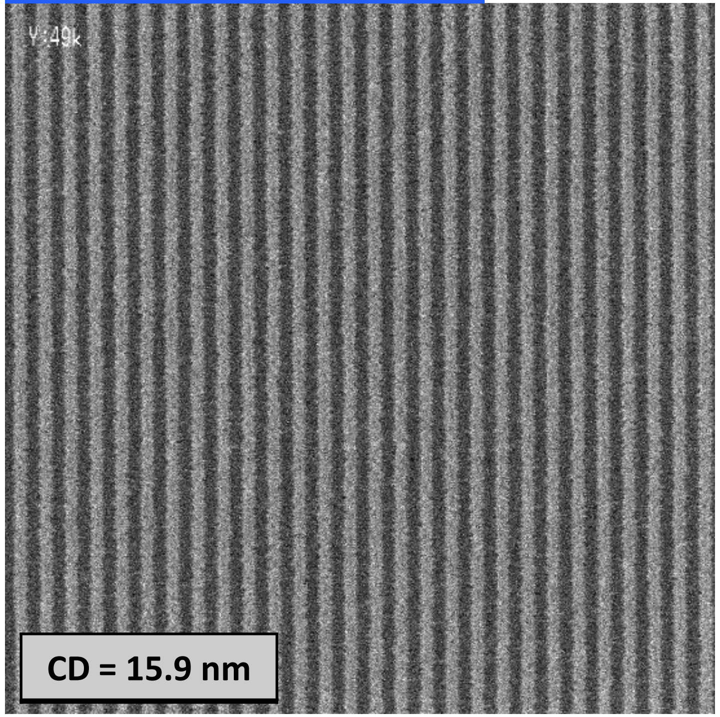
- Targeted design changes reduce D_{gel} while preserving contrast
- Multiple formulations tested with improved Esize vs LWR relative to baseline

16nm HP below 20 mJ/cm^2

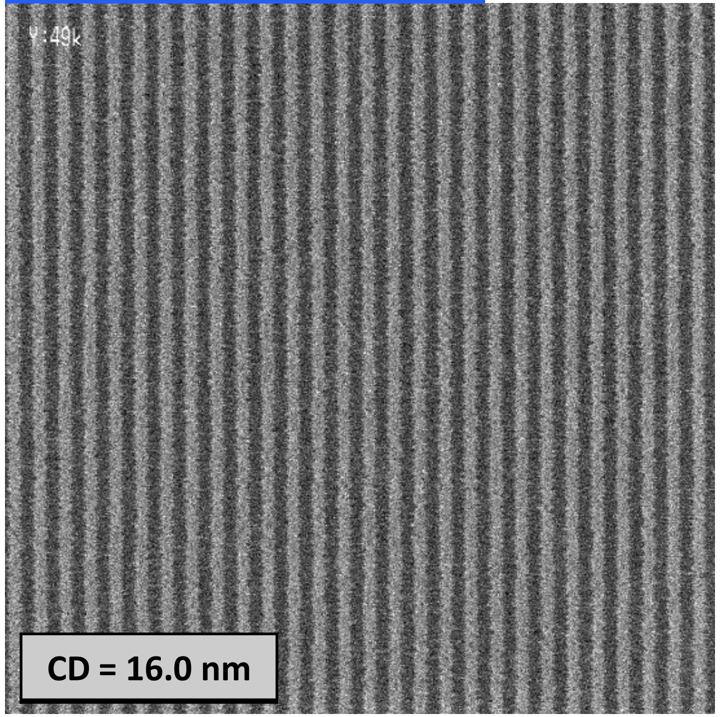
24 mJ/cm^2
3.6 nm LWR



18 mJ/cm^2
4.2 nm LWR



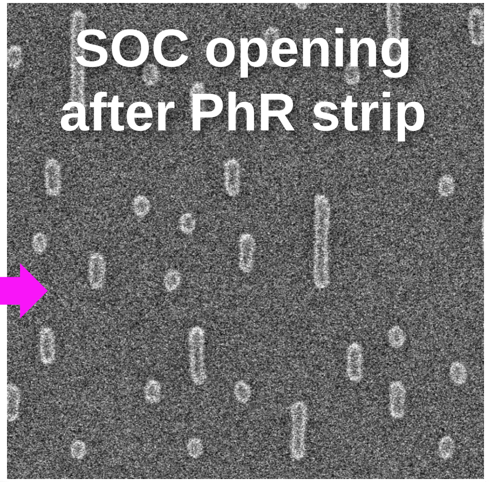
14 mJ/cm^2
5.1 nm LWR



NXE:3300, Dipole 60x

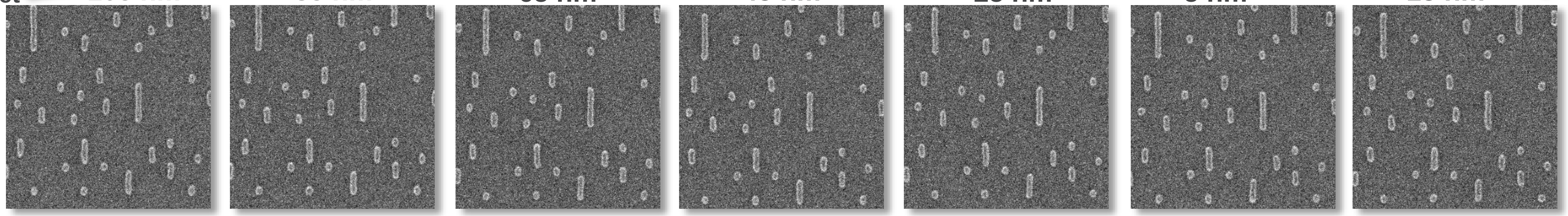
Integrating New Formulations in IMEC M2 Process

NXE3300 – NO RETICLE BIAS, CD-X 21nm ± 10%



	Baseline	Next Gen.
Dose [mJ/cm^2]	49	19
EL %	22	22
DOF @10%EL [nm]	118	120
CDU (3σ) [nm]	1.8	TBD

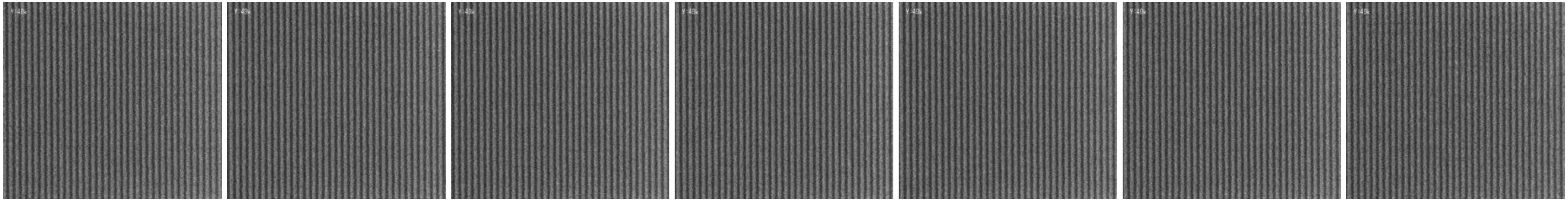
Focus offset

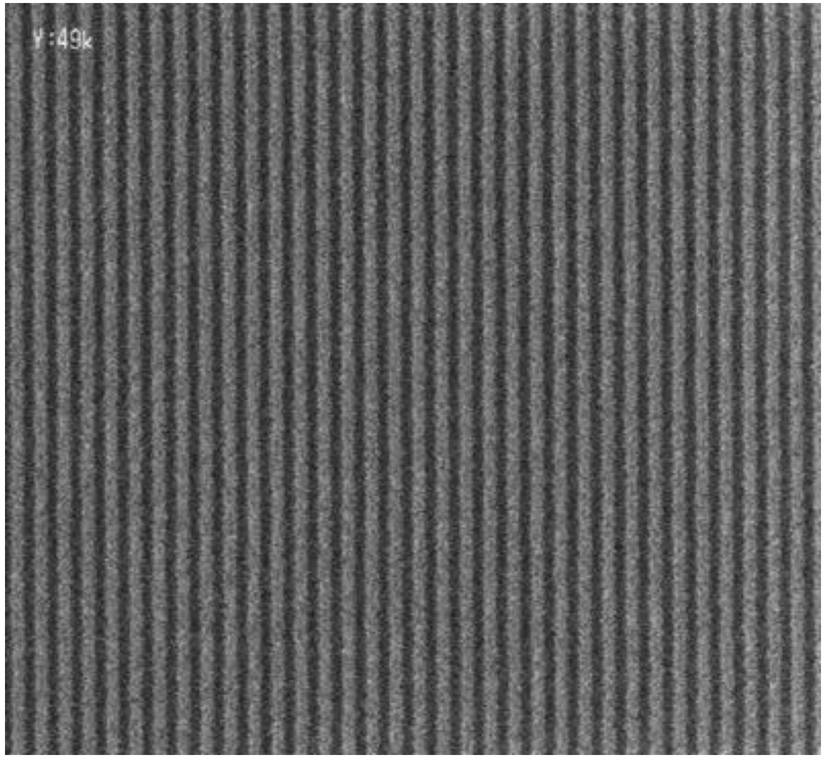


NXE:3300, Dipole 60x

Beyond N7: 13nm LS @ 26 mJ/cm^2 w/ Process Window

-60nm | **-40nm** | **-20nm** | **Focus: 0nm** | **20nm** | **40nm** | **60nm**





- NXE3300, Dip45x
- 13nm L/S – No Bias
- EL_{max}: 17%
  DOF@10%EL: 140 nm
- **Dose to size: 26 mJ/cm^2**

27.0 mJ/cm^2
13.2 nm CD
4.6 nm LWR

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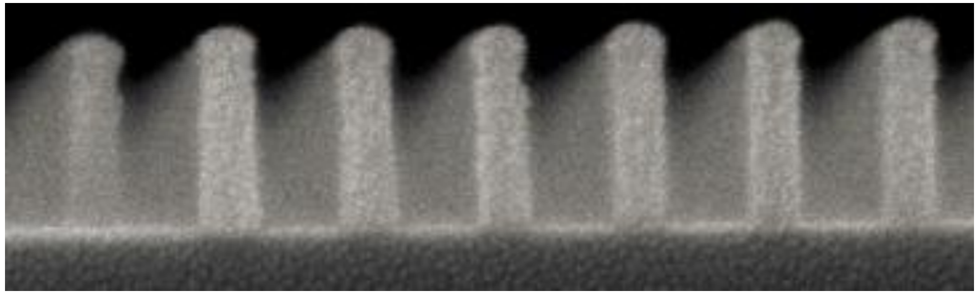
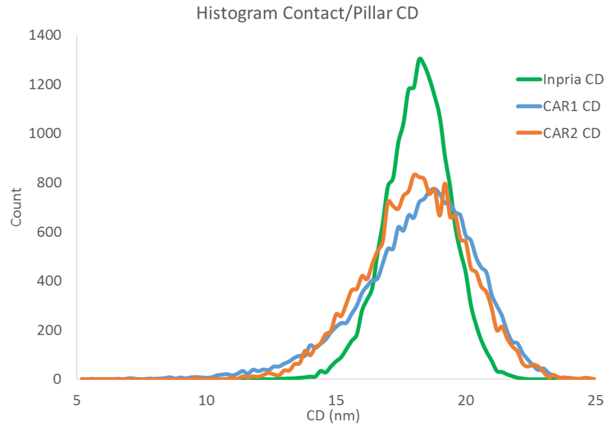
Summary

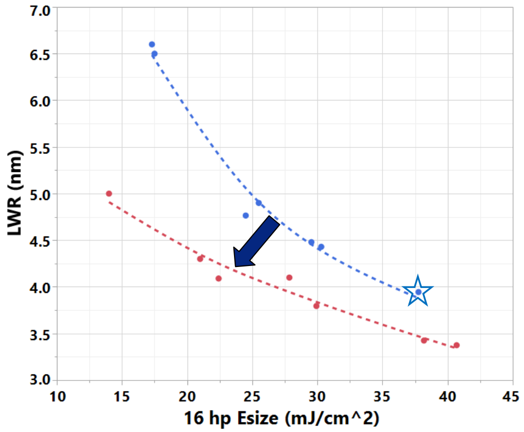
Sampling baseline resist for process development and fab integration

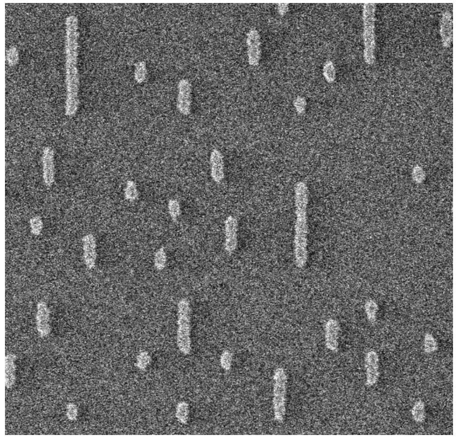


High absorbance and small photoactive building blocks lower initial stochastic variability



Improved dose vs LWR:
< 20 mJ/cm² at N7 pitches





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MOx Outlook

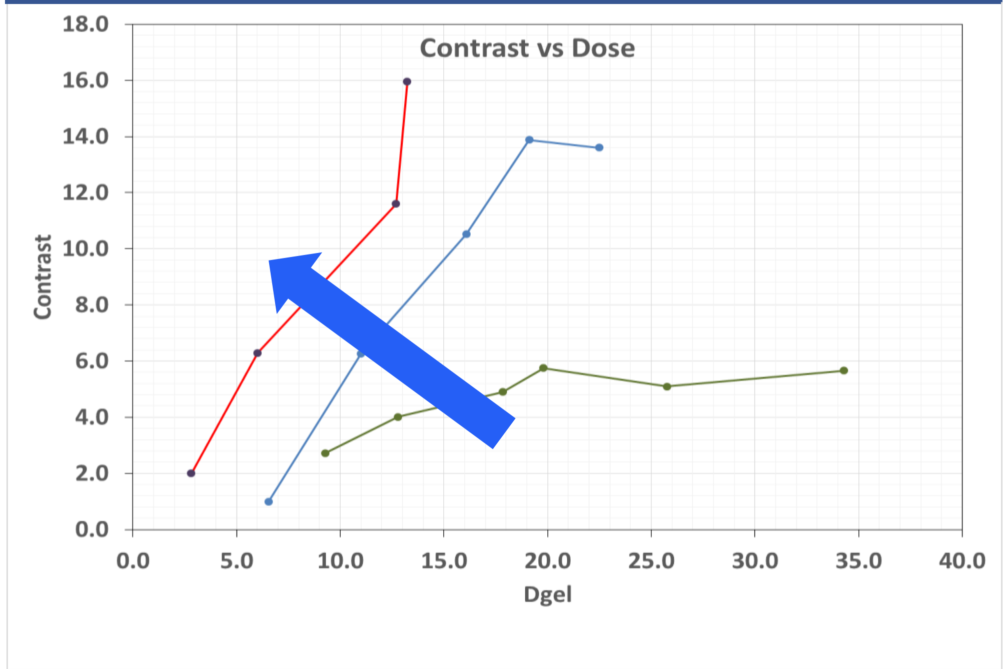
- **Low photon / material stochastic variability**
- **Competitive LWR-Dose**

But what are the real limits?

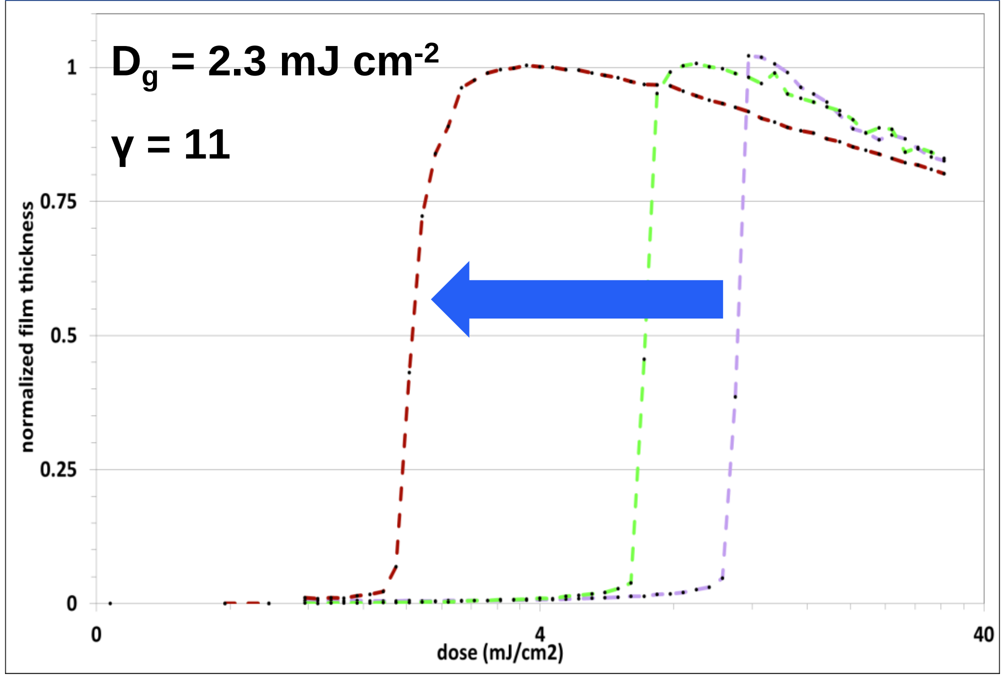
Better MOx Modeling → parameterize descriptive understanding of MOx resists

Chemistry Headroom

Effective Quantum Yield



Solubility Change / Radiation Event



THANK YOU

... and all of our partners