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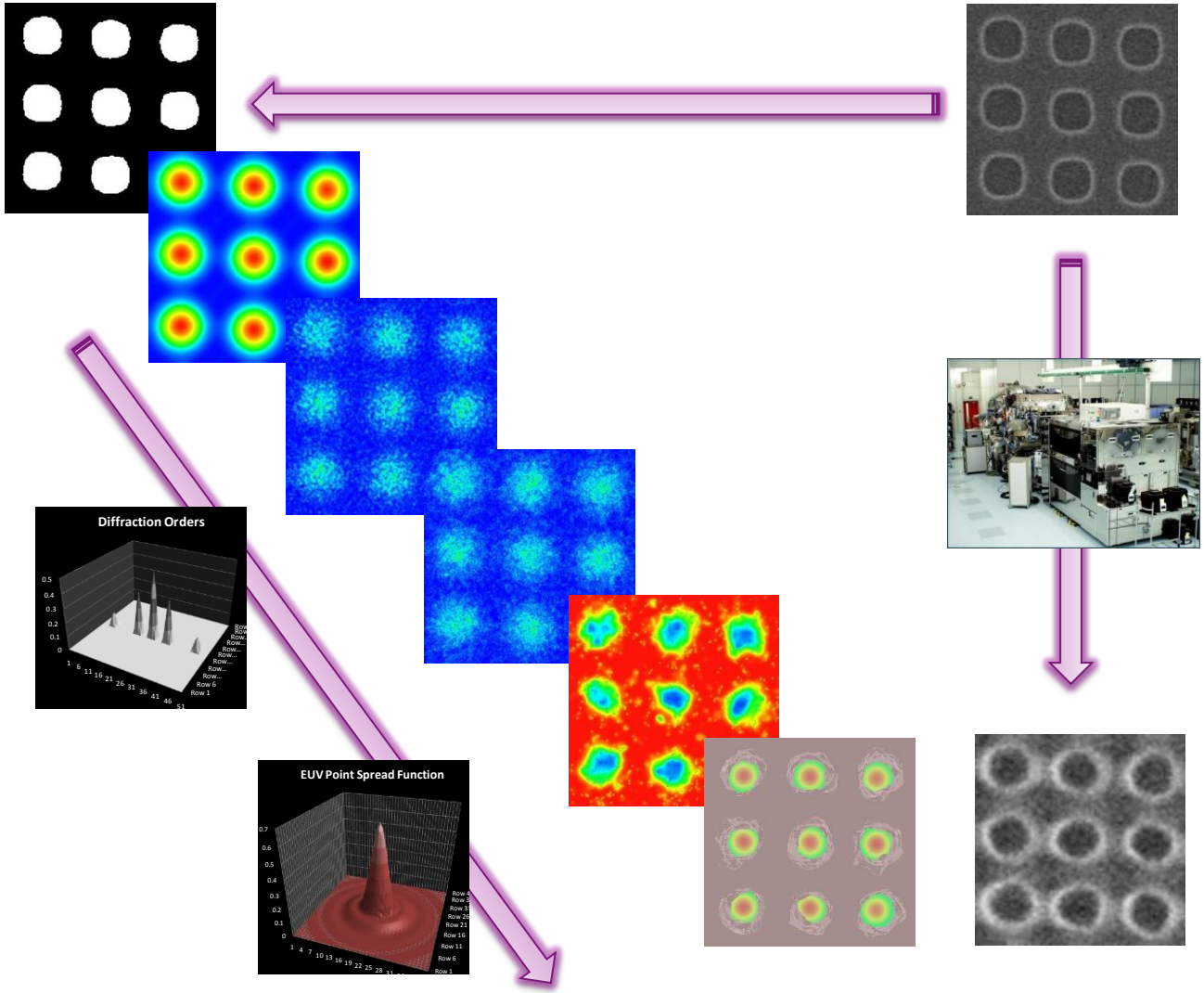
STOCHASTIC LIMITATIONS FOR EUV RESIST KINETICS TOWARDS THE 16 nm NODE

ALESSANDRO VAGLIO PRET, KONSTANTINOS GARIDIS, ROEL GRONHEID (IMEC)

JOHN BIAFORE (KLA-TENCOR)

imec

VARIABILITY ROOT CAUSES



1. Mask Uniformity
2. Photon distributions
3. Acid generation
4. Deprotection variability
5. Development Uniformity

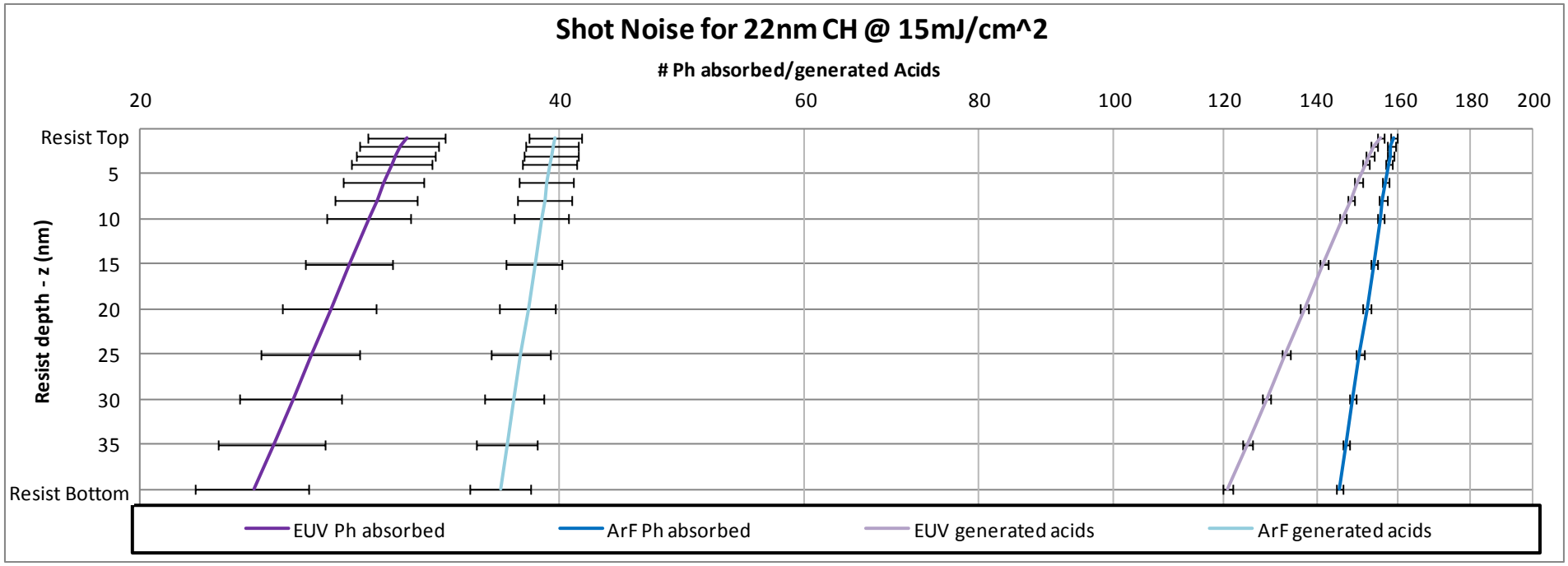
OUTLINE

1. Shot Noise: from photons to acids
2. Stochastic Prolith: going towards 16 nm hp
   - ADT EUV exposure data-set
   - Variability root cause(s): from mask to wafer
3. Available knobs
4. Conclusion

SHOT NOISE: THEORETICAL APPROACH

Wavelength (nm)	k (α μm^{-1})	QY	Available # Ph/CH area	Available # Ph/nm^2	Ph lost
13.5	0.0068 (6.3)	5.00	4931	~10	78%
193	0.0347 (2.3)	0.25	70488	~146	91%

$$\alpha = 4\pi * \frac{k}{\lambda} \qquad \#Ph = dose * \frac{\lambda}{c * h} \qquad Ph_{abs} = Ph_i * \left(1 - e^{-\alpha t(z)}\right) \qquad H^+_{gen} = Ph_{abs} * QY$$



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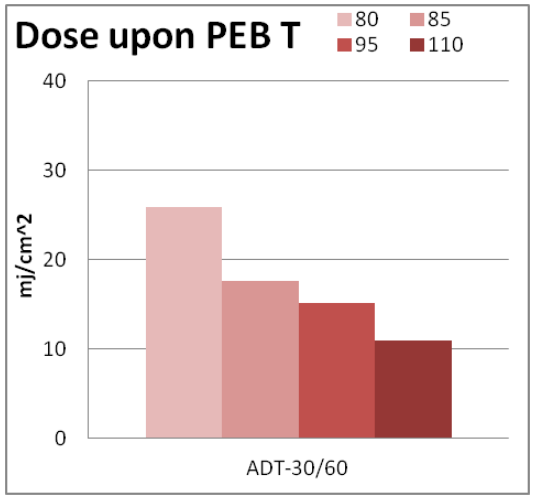
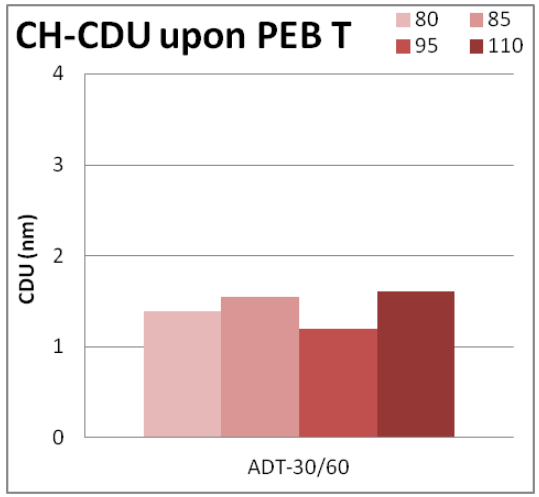
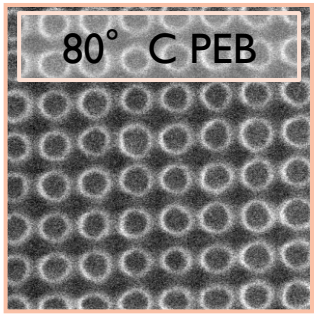
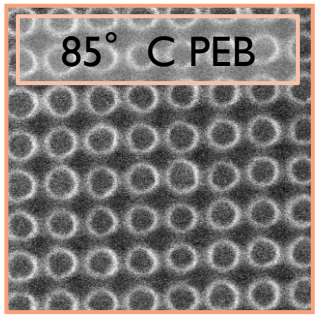
ADT EXPOSURE DATA SET

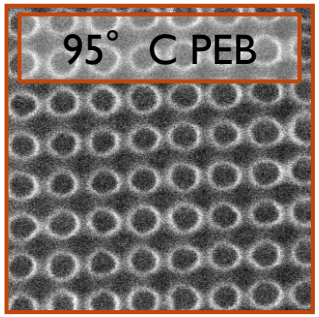


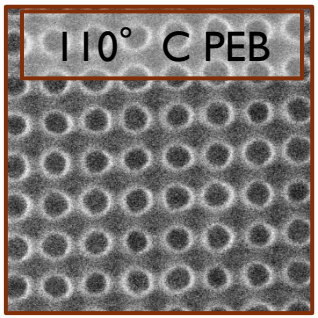


CH, L/S FEMs of different structures @ different PEB were considered for the calibration model









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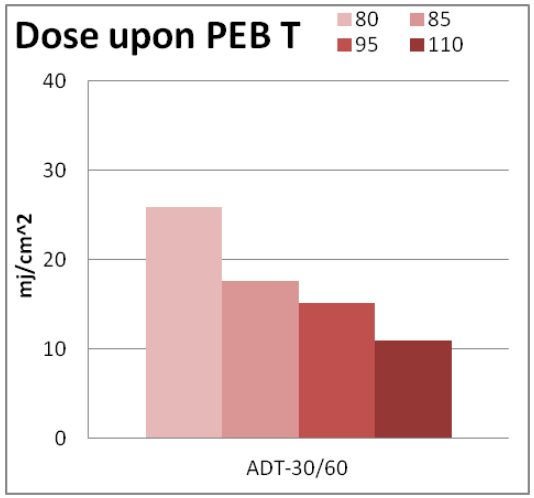

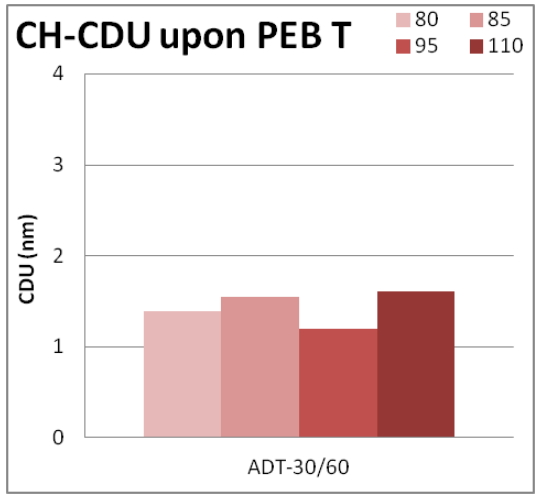

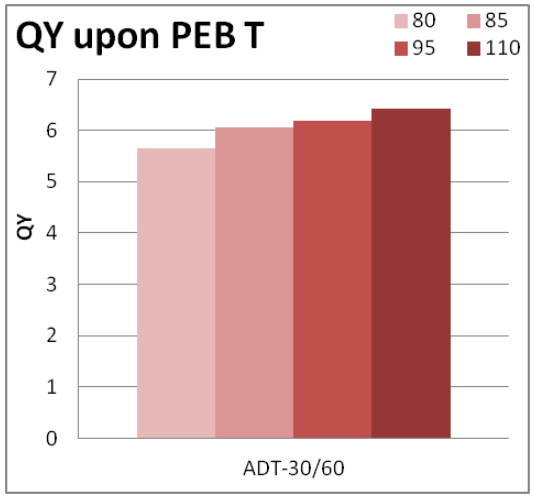

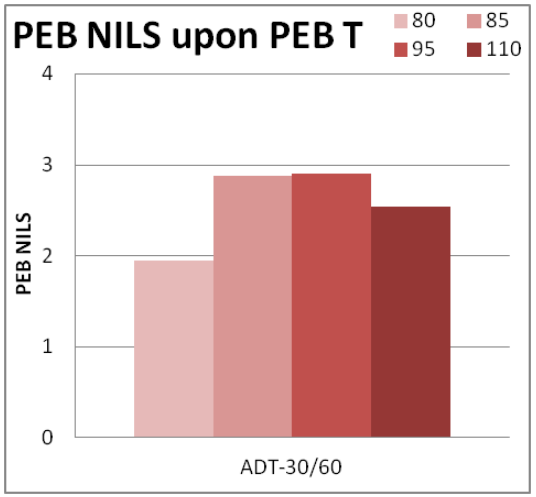

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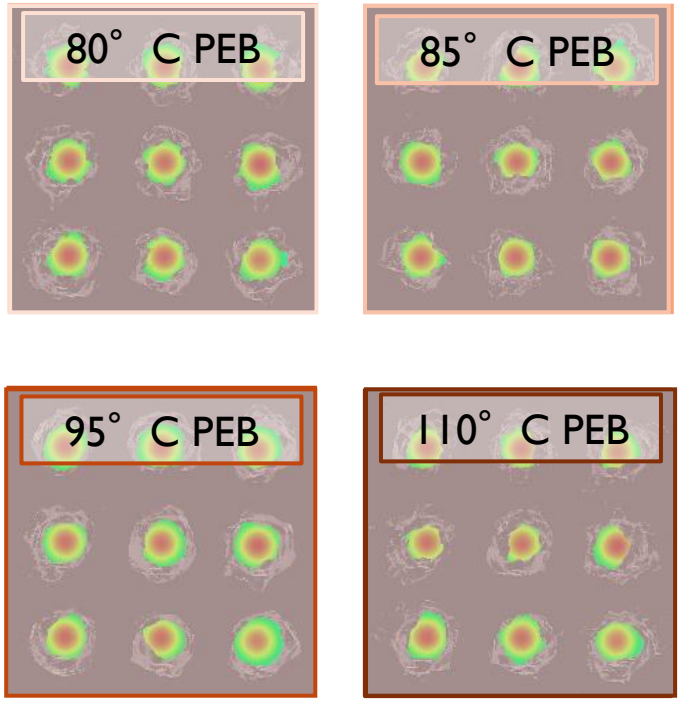
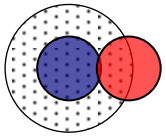
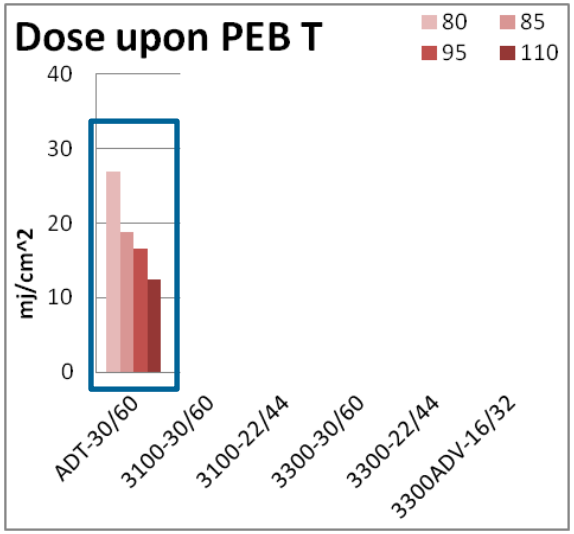
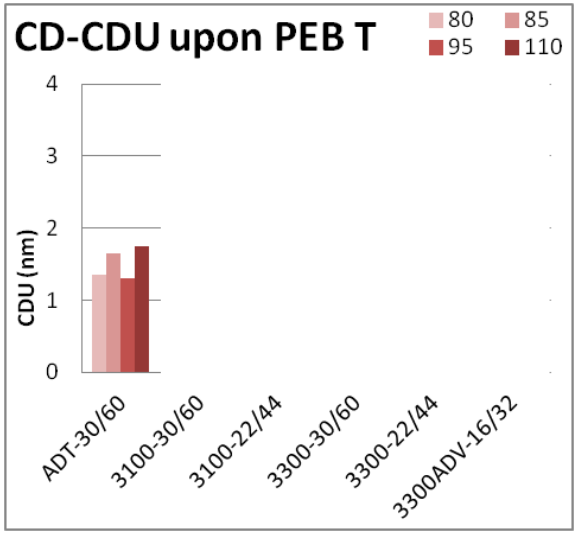


TOWARDS 16nm: NXE 3100/3300

ADT







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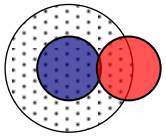
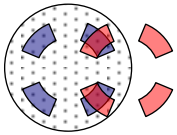
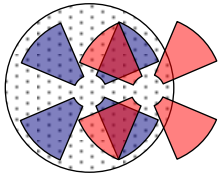


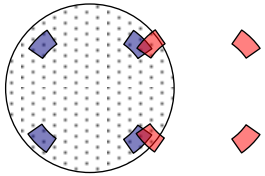
NXE: 3100

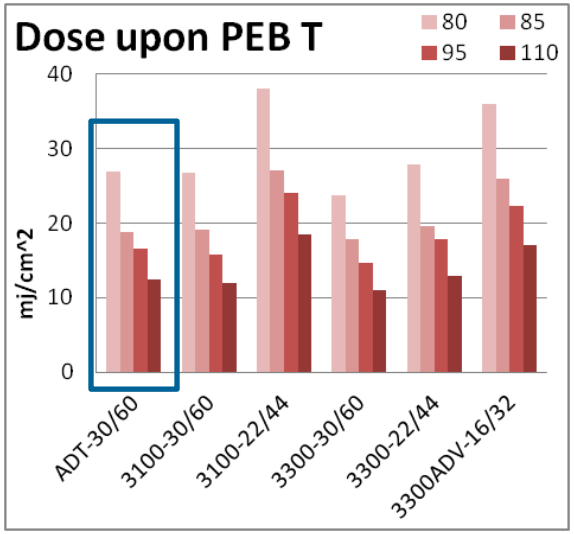


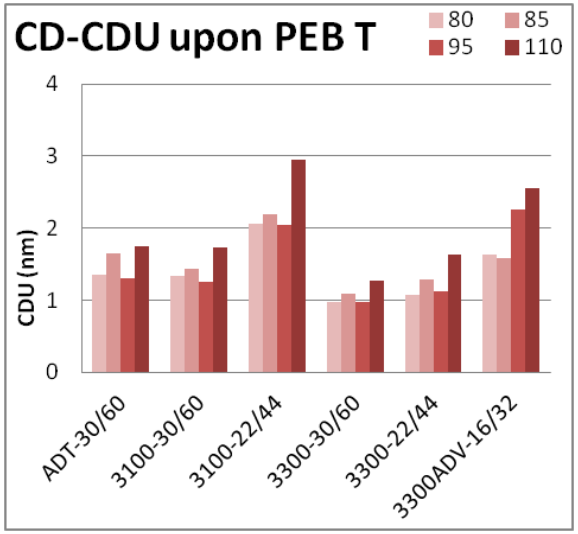
NXE:3300



NXE:3300ADV.



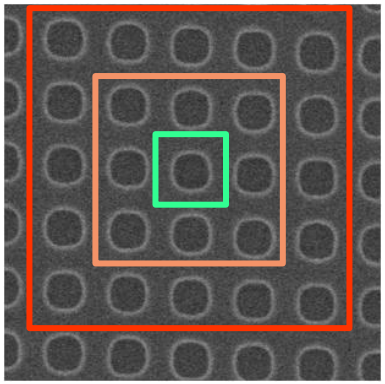




1. 22 nm hp CH barely printable on NXE:3100
2. 16 nm hp CH barely printable on NXE:3300
3. Aerial image plays a fundamental role, but only @ high k_1
4. Chemical contrast needed for CDU trends

VARIABILITY ROOT CAUSES: MASK CONTRIBUTION

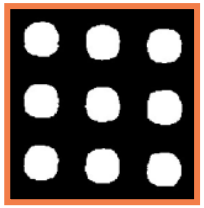
Mask CD-SEM image



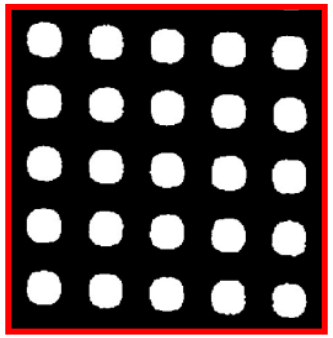
Prolith Mask modeling

Ideal case

9 CHs



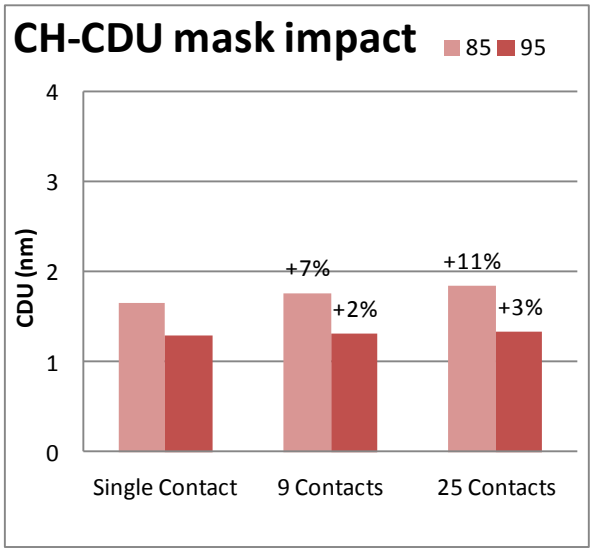
25 CHs



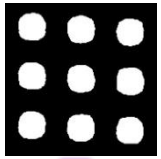
Mask contribution was evaluated simulating

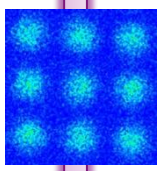
1. 1 "real" CH (ideal case) * 250
2. 9 "real" CHs * 28
3. 25 "real" CHs * 10

for 85° and 95° PEB

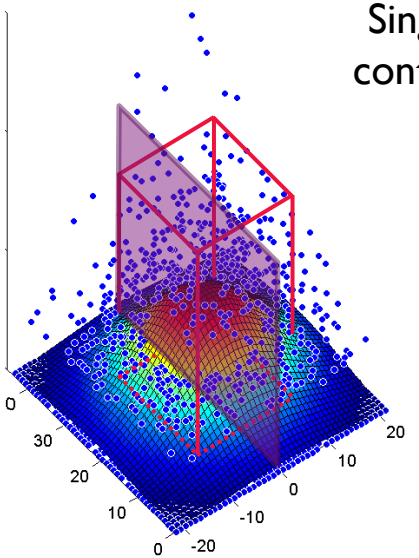


VARIABILITY ROOT CAUSES: PHOTON DISTRIBUTION

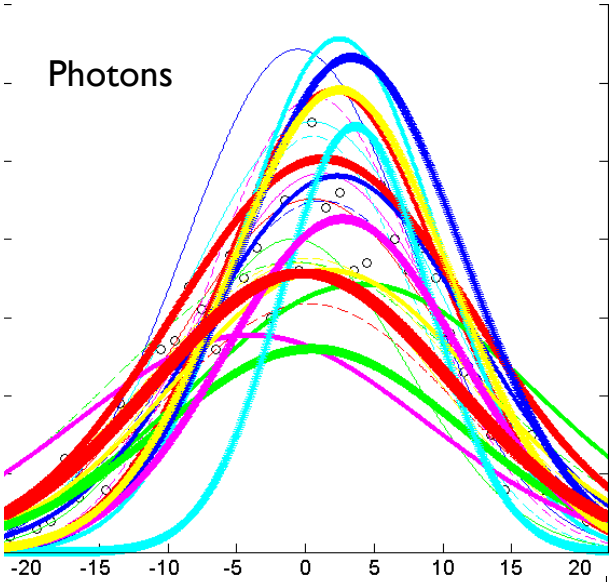




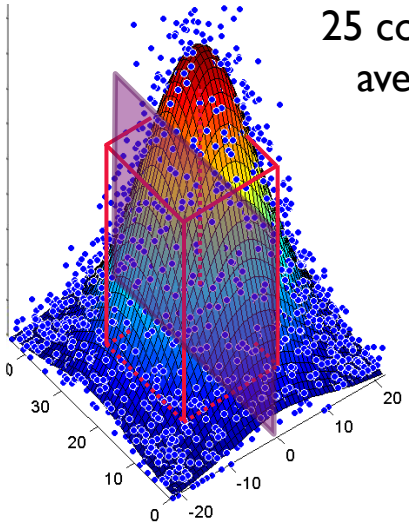
Single contact



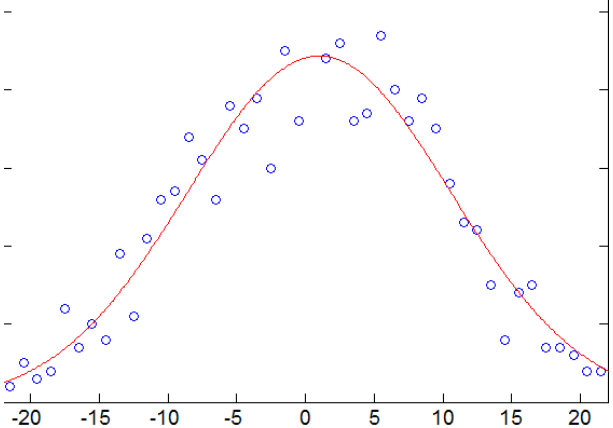
Photons



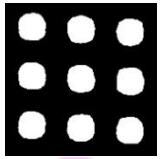
25 contacts average

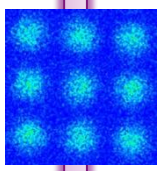


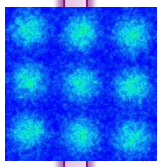
Gaussian σ distribution→ CD variability



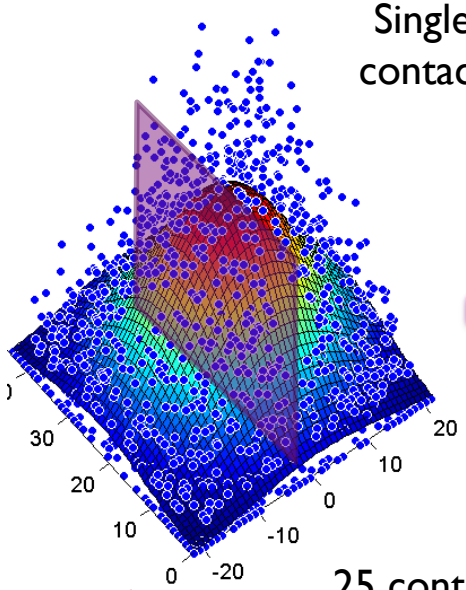
VARIABILITY ROOT CAUSES: ACID DISTRIBUTION

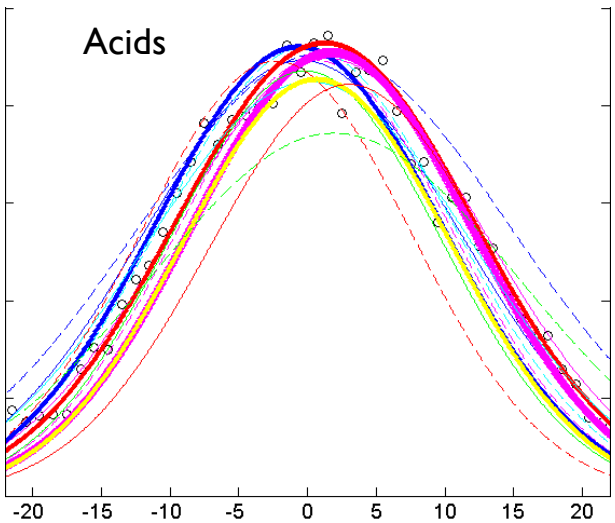




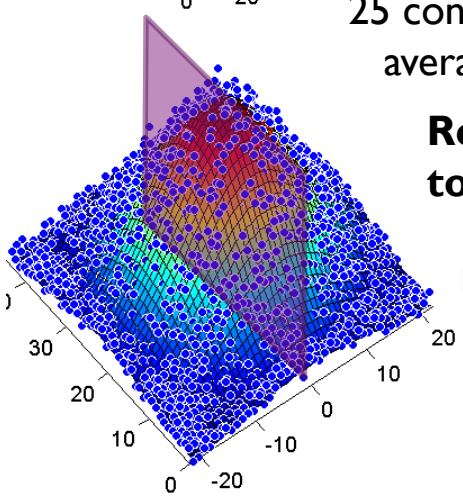


Single contact

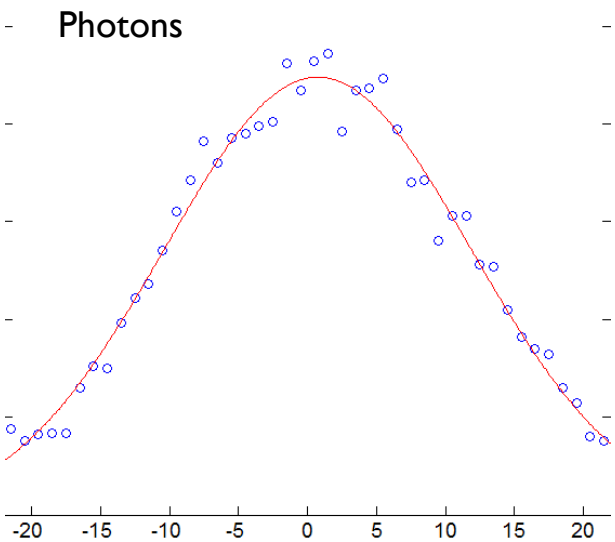




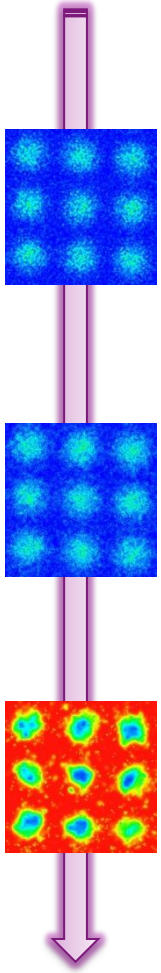
25 contacts average

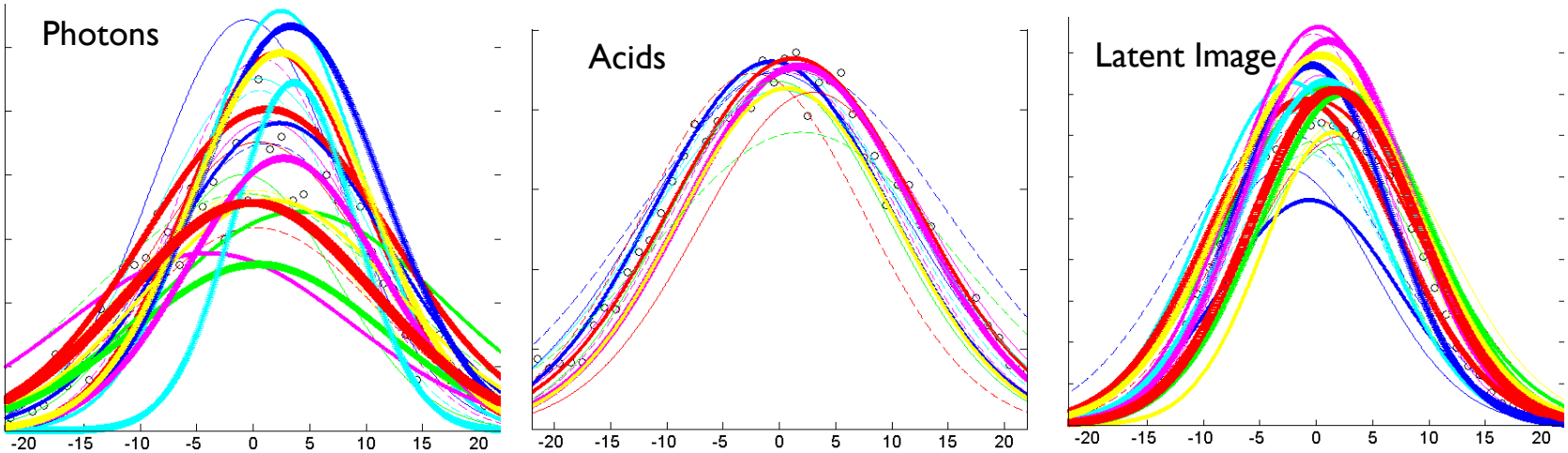


Rectifying effect due to high QY for EUV



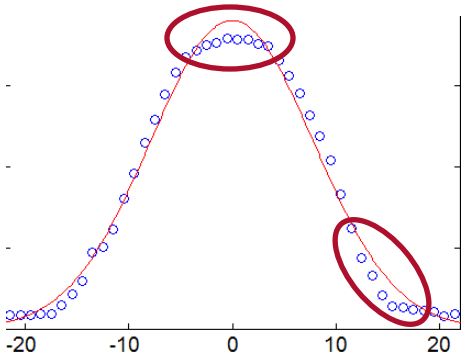
VARIABILITY ROOT CAUSES: DEPROTECTION VARIABILITY

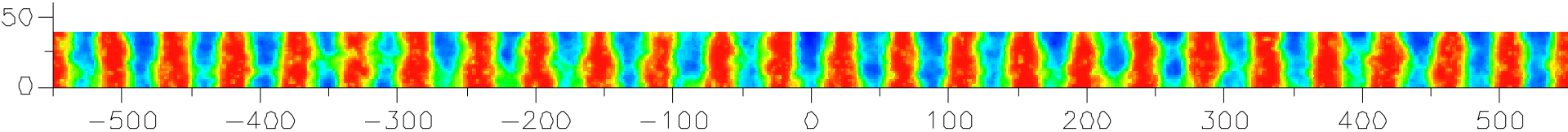




Latent Image: Higher variability in Gaussian profile compared to Acid distributions

Poor Gaussian Fit → variability evaluated directly on latent image CD





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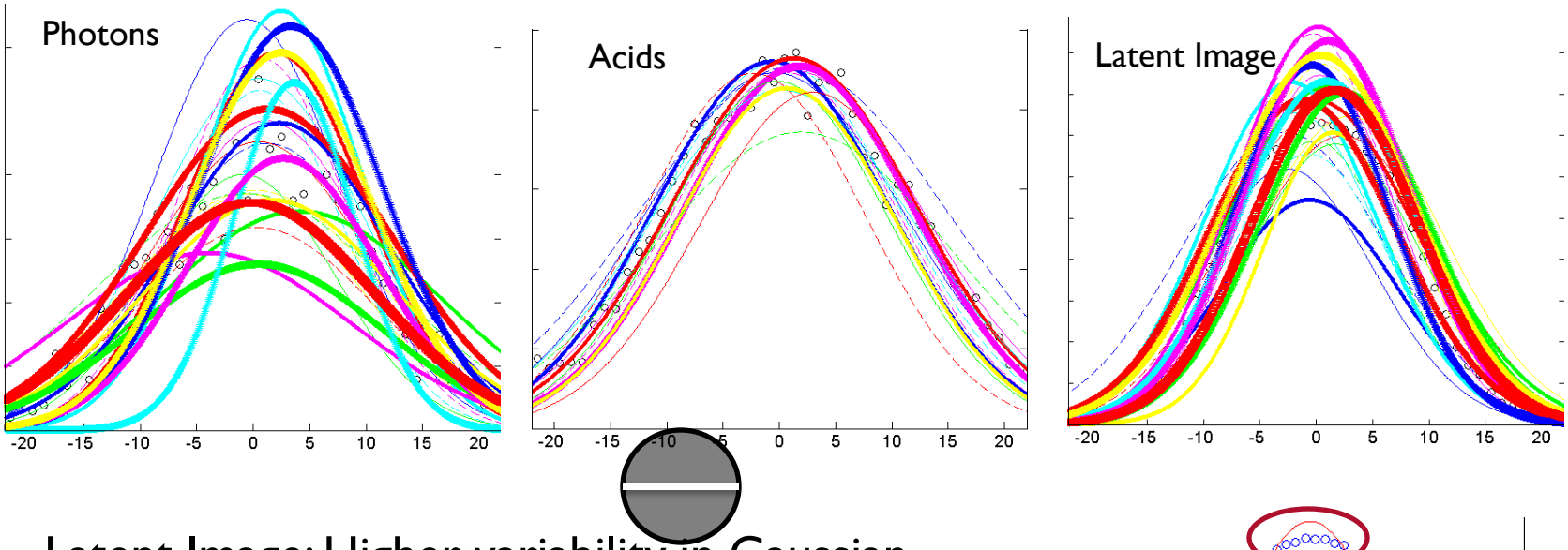

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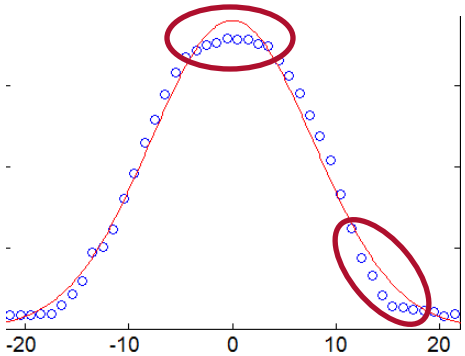
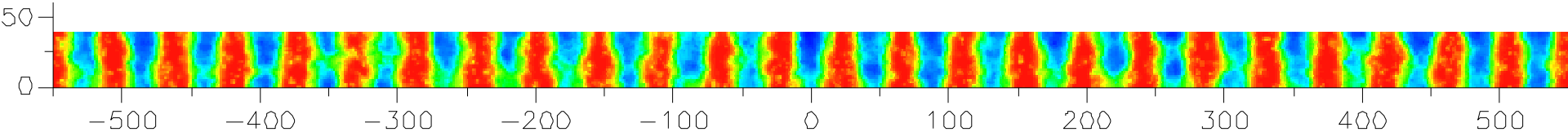
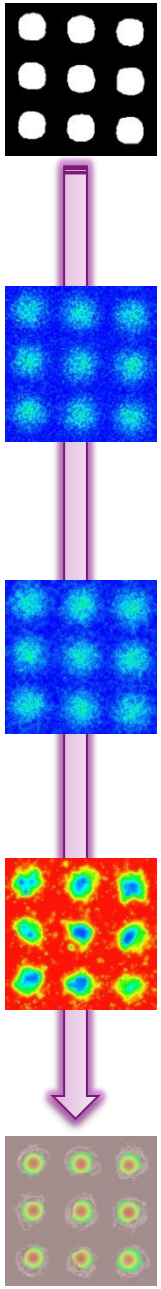
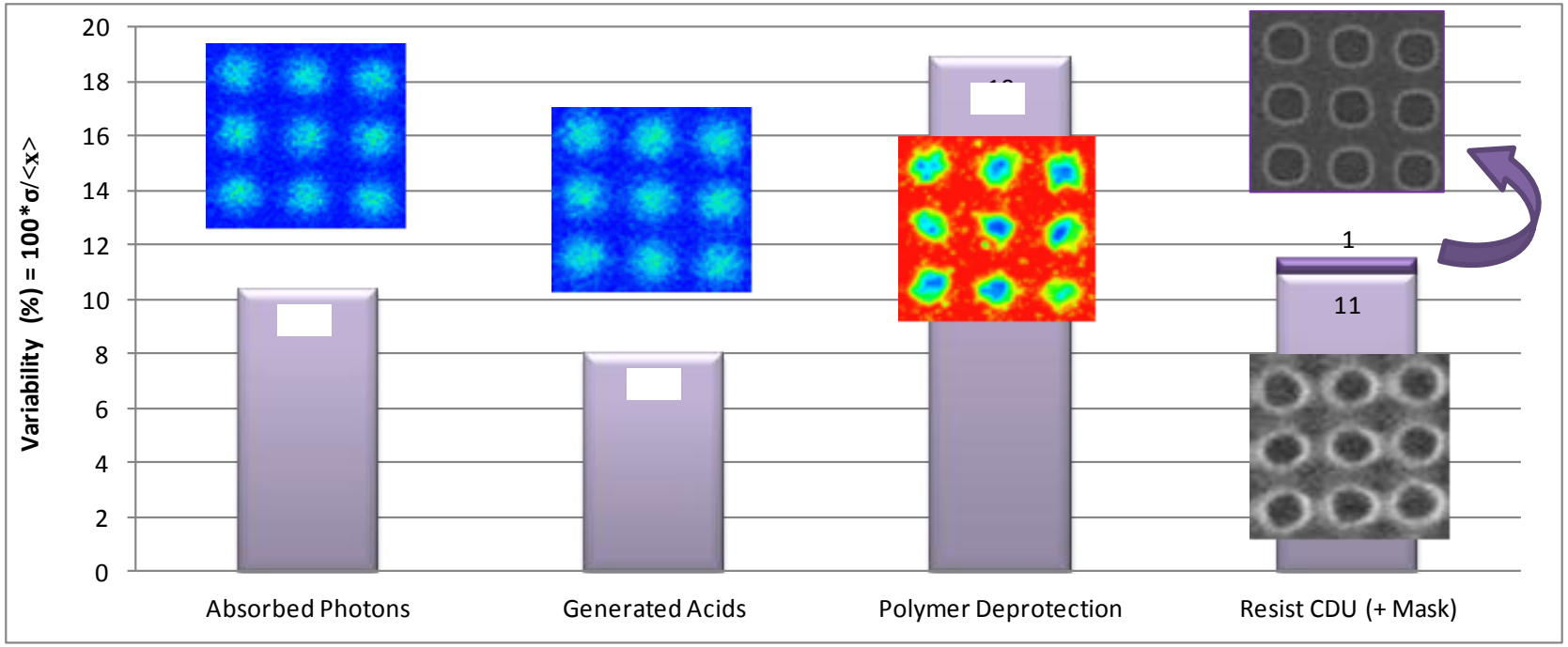




VARIABILITY (%) FOR SEVR140 - 22nm CH ON NXE: 3300





1. Mask contribution for CH: negligible
2. PSN contribution can be smoothed by high QY
3. Deprotection step increases CD variability
4. Development partially reduces deprotection variability

OUTLINE

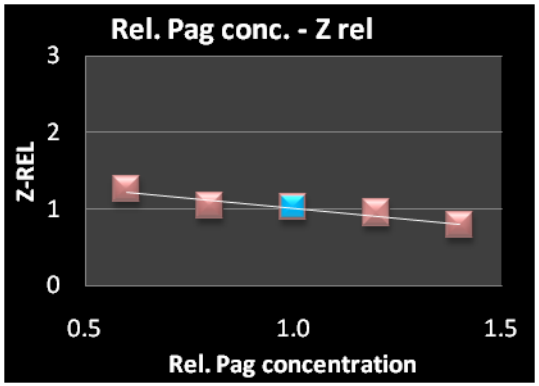
1. Shot Noise: from photons to acids
2. Stochastic Prolith: going towards 16 nm hp
   - ADT EUV exposure data-set
   - Variability root cause(s): from mask to wafer
3. Available knobs
4. Conclusion

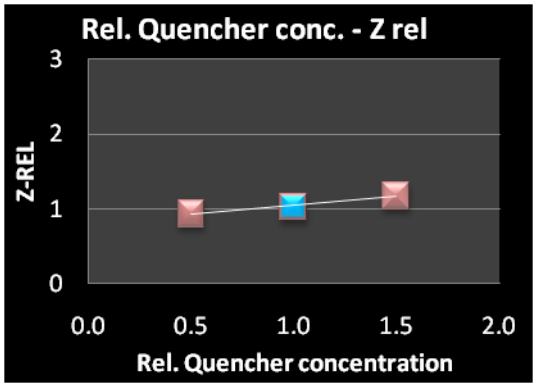
RESIST OPTIMIZATION

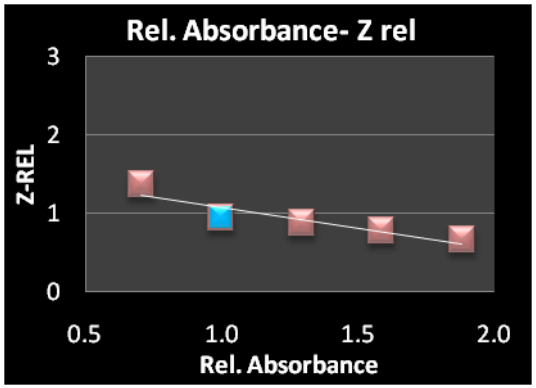
	SEVR140
Dose (Sensitivity)	17.9
CDU (LWR)	**1.11**

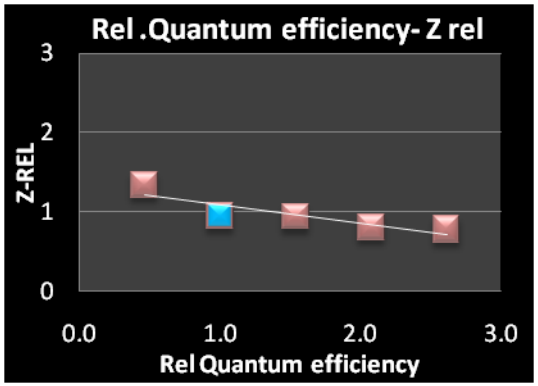
$$Z - FACTOR = RES^3 * LWR^2 * SEN^1$$

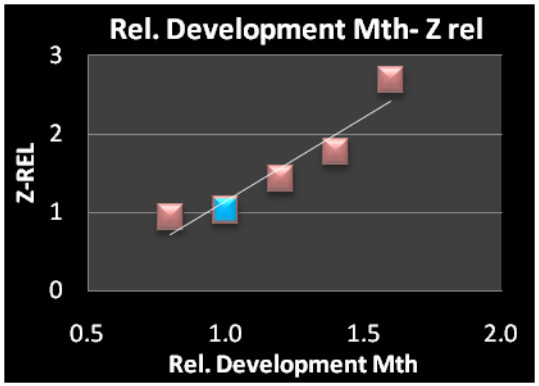
$$Z - REL = \frac{CDU^2 * SEN^1}{Z - REL_{SEVR140}}$$









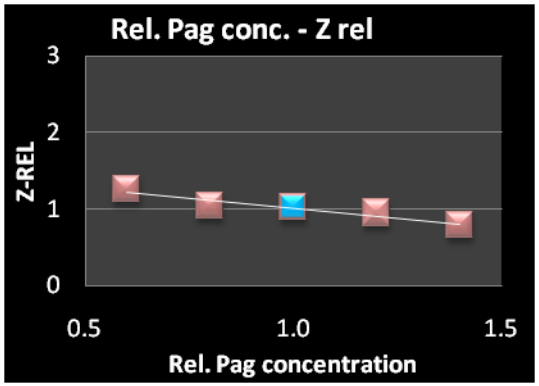


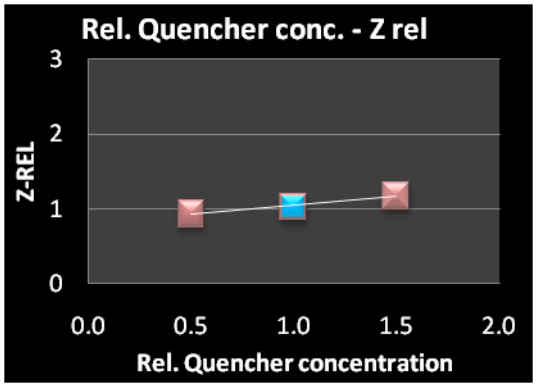
RESIST OPTIMIZATION

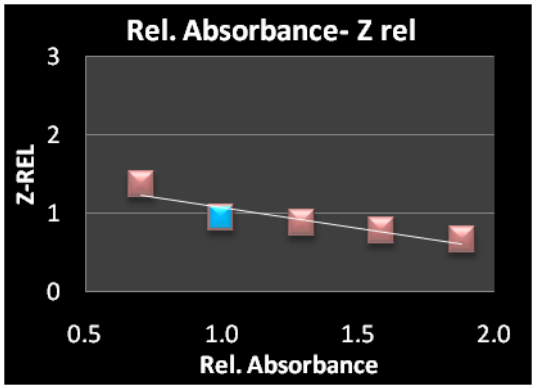
	SEVR140	Alex-1	Alex-6	Alex-9
Dose (Sensitivity)	17.9	20.6	8.2	34.0
CDU (LWR)	**1.11**	**0.97**	**1.11**	**0.78**

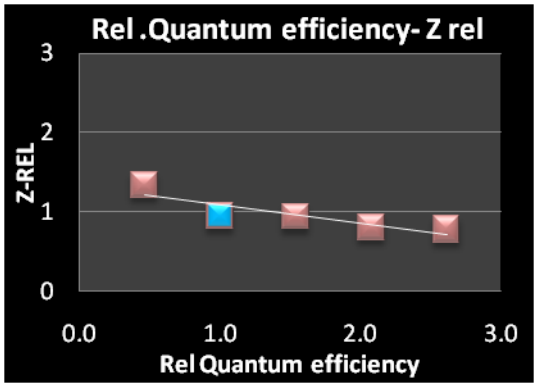
$$Z - FACTOR = RES^3 * LWR^2 * SEN^1$$

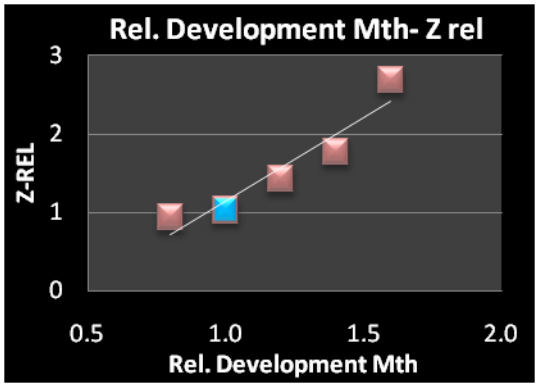
$$Z - REL = \frac{CDU^2 * SEN^1}{Z - REL_{SEVR140}}$$





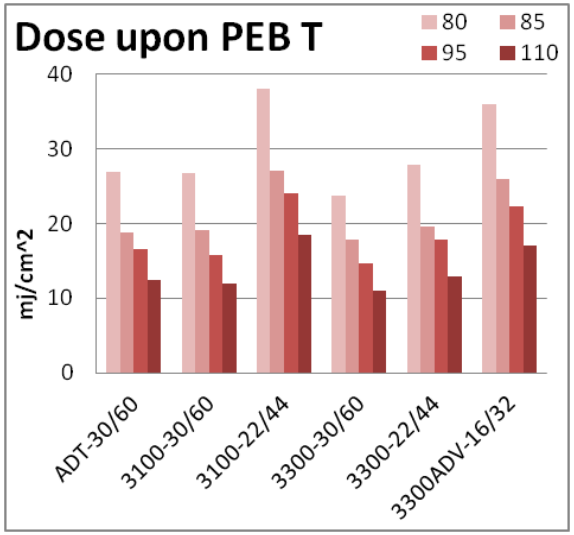


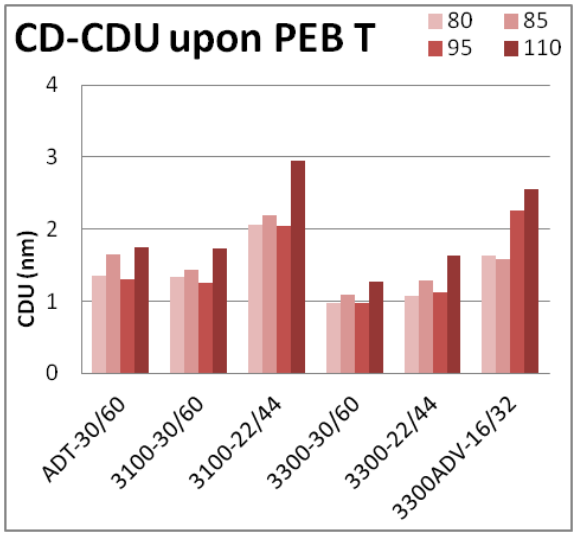




NEGATIVE TONE DEVELOPMENT: ...JUST A TIP...

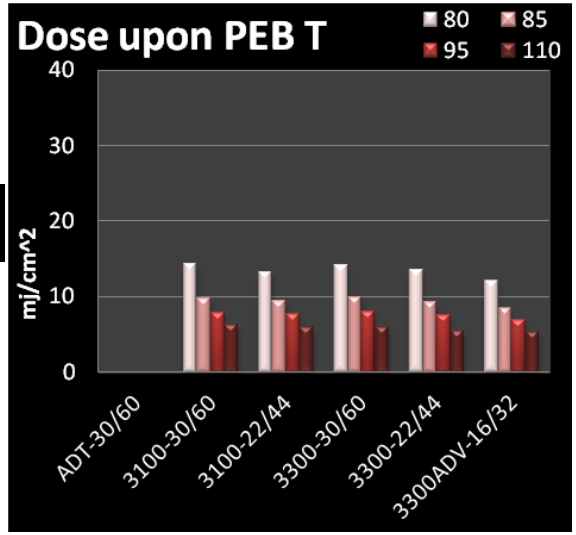
POSITIVE

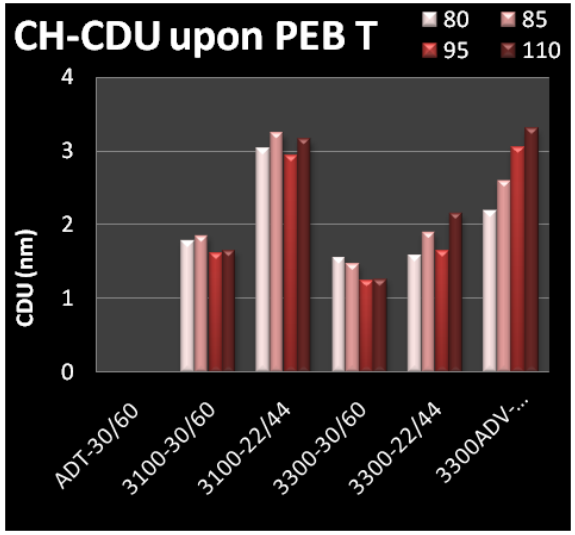




...just imagine a NTD as performing as SEVR140 (Alex-0)

NEGATIVE





OUTLINE

1. Shot Noise: from photons to acids
2. Stochastic Prolith: going towards 16 nm hp
   - ADT EUV exposure data-set
   - Variability root cause(s): from mask to wafer
3. Available knobs
4. Conclusion

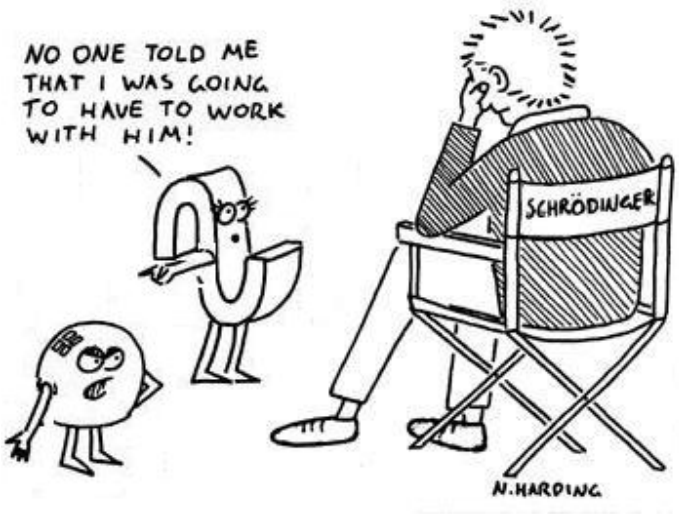
SUMMARY

1. Mask CDU impact is negligible for CH

2. Photon Shot Noise impact on pattern variability is inevitable, going towards smaller features/lower doses/higher photons energy, however:

   1. Resist Absorbance can be still increased to improve the photon spatial distribution density with small impact on SWA
   2. High Quantum Yield smoothen the PSN effect (high acid generation means lower Acid Shot Noise)
   3. Deprotection variability can be improved tuning M_{th}

3. Negative Tone Development platforms may be used to increase sensitivity/reduce pattern variability



Thank you for your attention

OBJECTIVE EXPERIENCE IS DISCRETE BUT THE WORLD HANGS TOGETHER BY THE GRACE OF CONTINUITY

ZENO