C–DEN
Center for Design-Enabled Nanofabrication
Berkeley UCLA UCSD

Workshop
Patterning
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Measuring chemical image in photoresist

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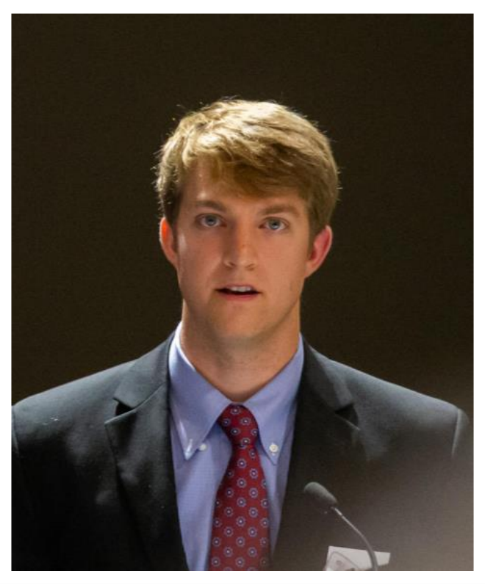


Motivation

- The RLS tradeoff remains a major roadblock for the future of EUV patterning
- The underlying cause of line edge roughness as well as catastrophic defects has not been pinpointed
- While models provide insight into the nature of the RLS tradeoff, experimental validation of their accuracy is paramount

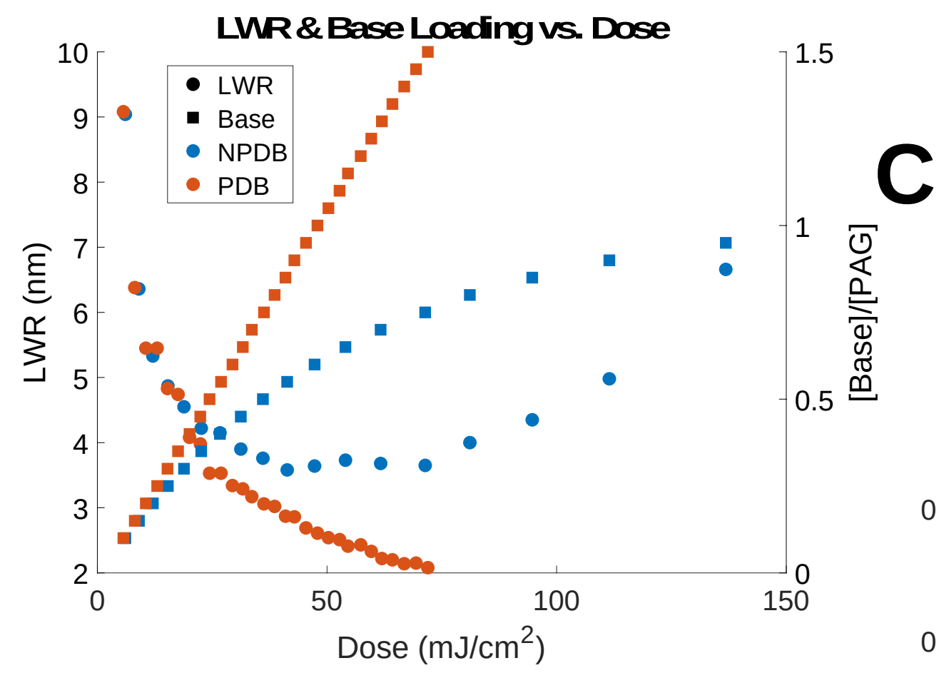
Objectives

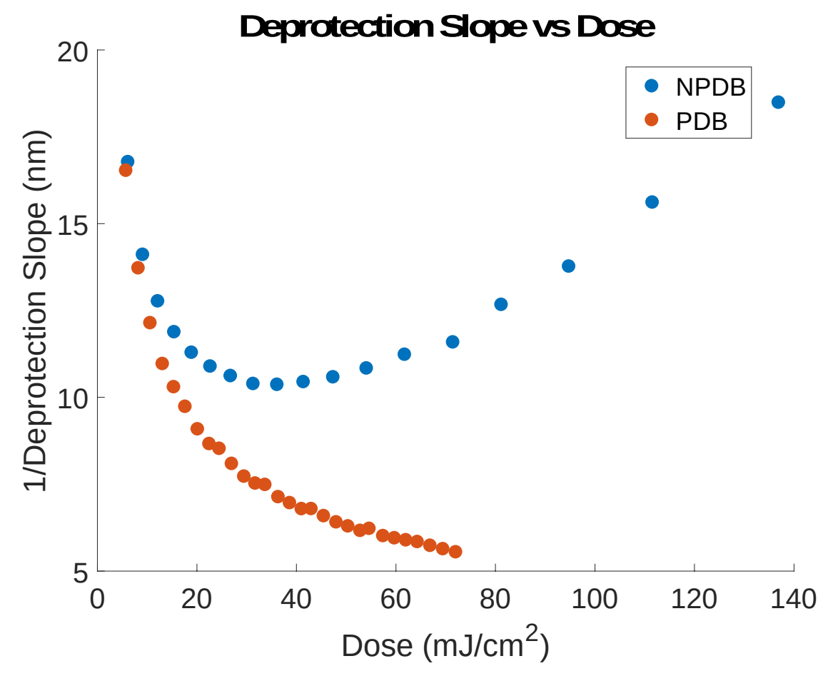
- Provide a model representative of the key components of the RLS tradeoff
- Use the model to explore potential RLS mitigation strategies
- Partner with industry to investigate the model predictions experimentally
  - Pre-development evaluation of chemical slope (and LER?) using RSoXS and AFM
  - Post-development evaluation of LER using SEM

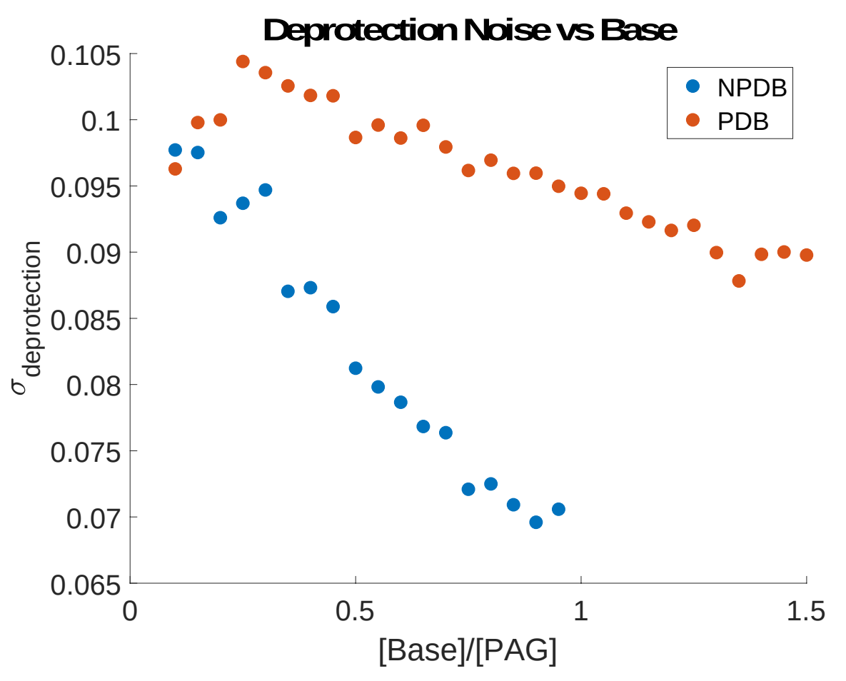
Multivariate Poisson Propagation Model

- Stochastically populates model cells according to a Poisson distribution. Mean values are given by nominal chemical loading/ aerial image intensity
- Deterministically simulates the reaction-diffusion process
- Predicts $LER = \frac{3*\sigma_D}{Slope}$

Modeling Results: Conventional vs PDB


LWR & Base Loading vs. Dose


Deprotection Slope vs Dose


Deprotection Noise vs Base

Modeling Conclusions

- Photo-decomposable base (PDB) can help to improve LWR relative to conventional quencher at a given dose
- This improvement is the result of an improvement in deprotection slope- a steeper slope results in less spatial line edge deviation given variation in deprotection level
- Deprotection noise is increased when using PDB

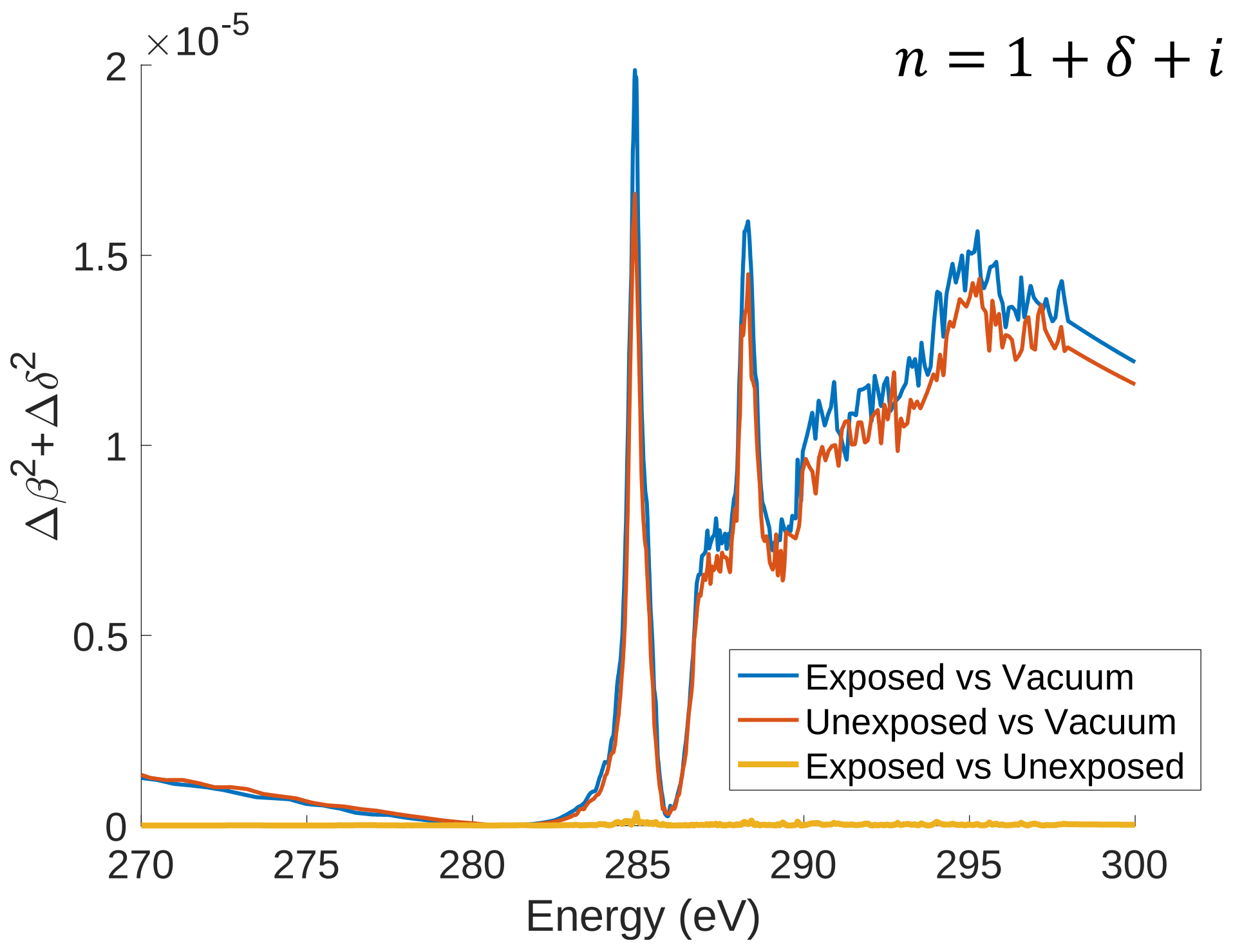
Experimental Verification

- To verify, we have partnered with industry to test a commercially-available photoresist with varying PDB loadings
- These resists will be patterned and studied pre-develop via RSoXS and AFM to determine chemical slope (and possibly roughness)
- Results will be compared with post-develop LER measurement obtained via SEM

RSoXS Basics

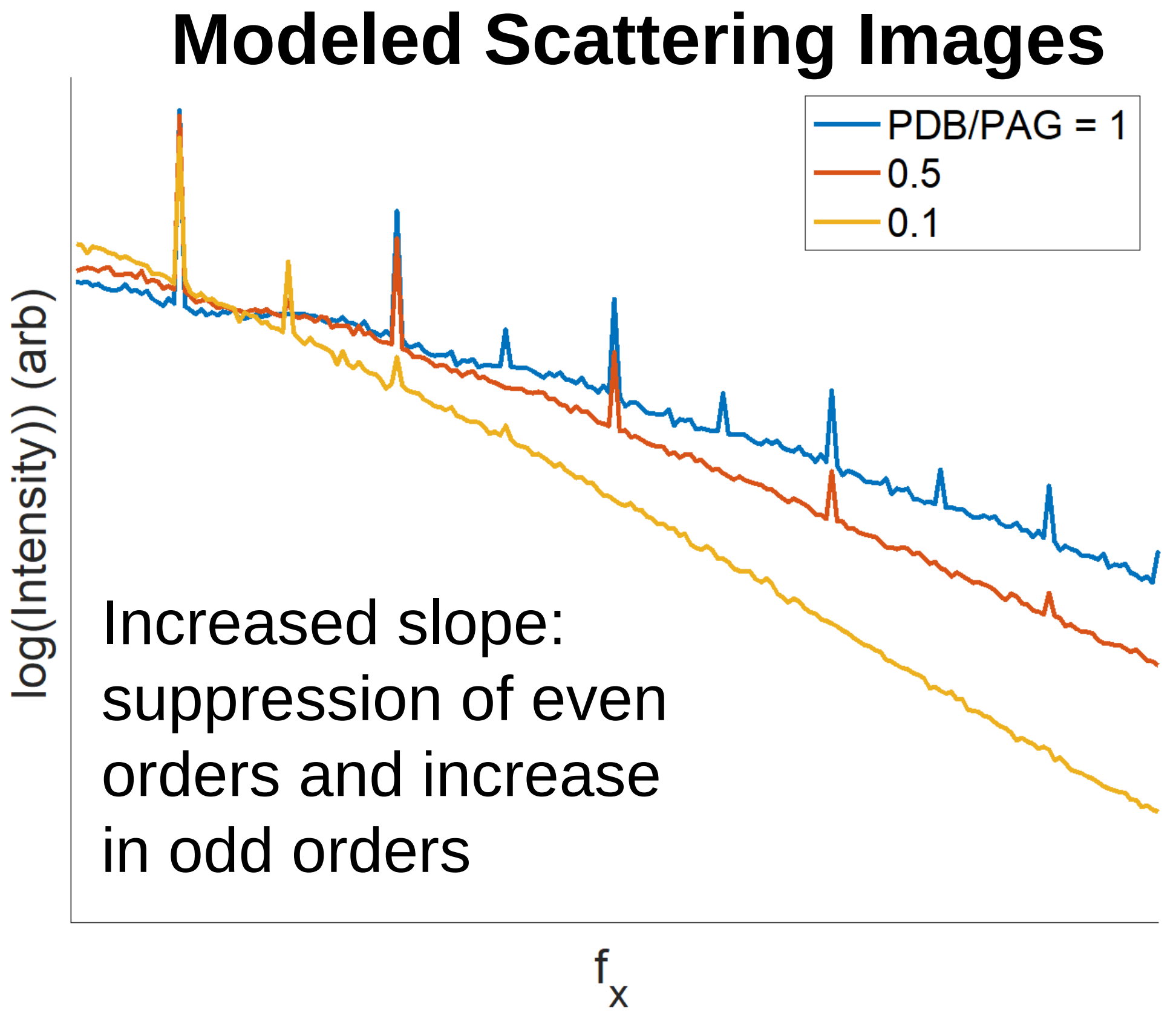
- Reaction-diffusion process of periodic patterns results in a chemical and physical diffraction grating
- Exploiting changes in effective electronic density, chemical grating can be studied via X-ray scattering
- Near a resonant edge, diffraction due to chemistry is especially pronounced
- Can use diffraction orders to calculate underlying grating structure

Scattering Contrast


$n = 1 + \delta + i\,\beta$

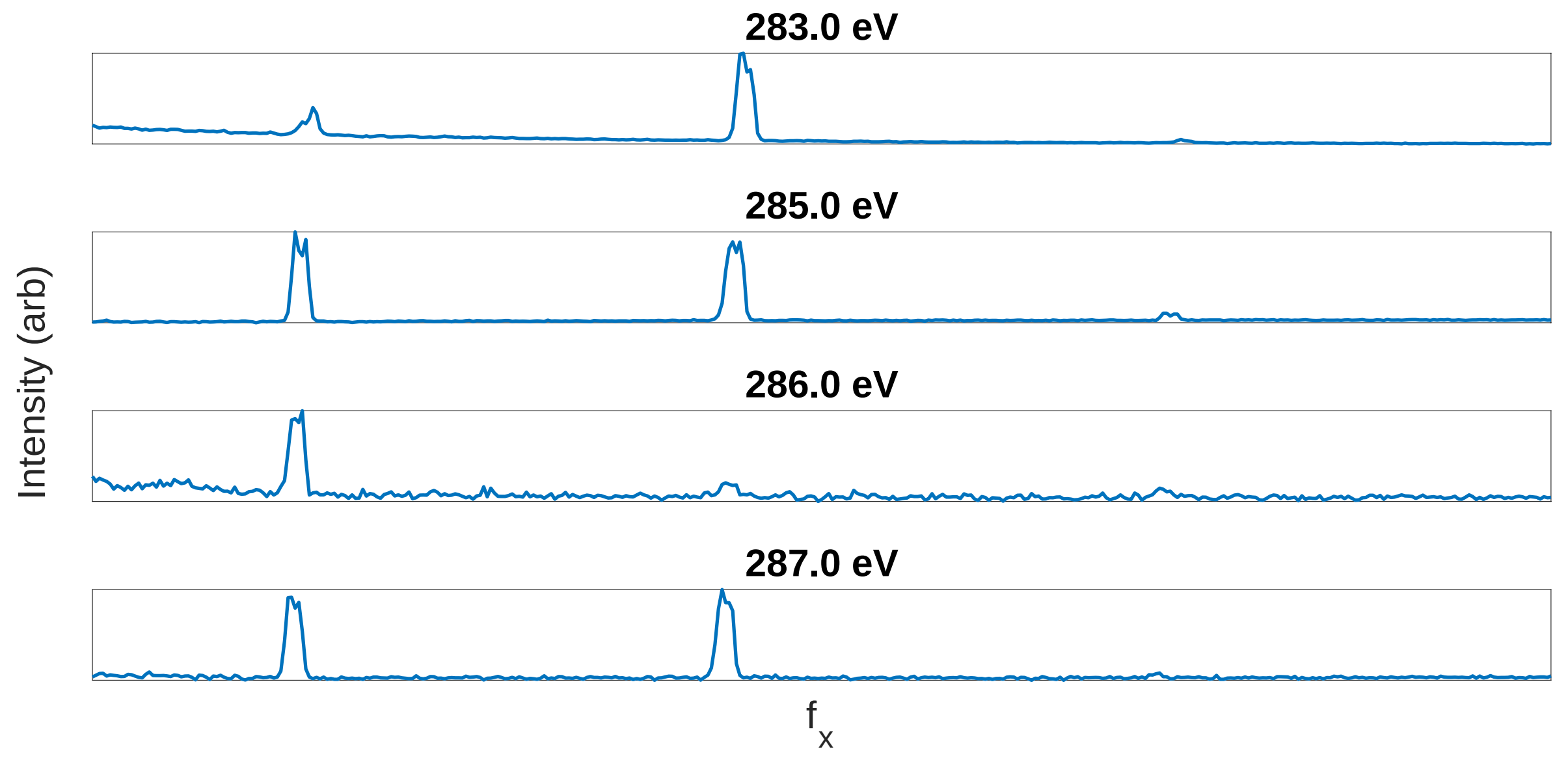
Freychet et al. SPIE 2018

Modeled Scattering Images



Increased slope: suppression of even orders and increase in odd orders

Preliminary Data



Experimental RSoXS data demonstrates adequate chemical contrast in latent image

AFM

- RSoXS measures the superposition of the physical and chemical diffraction gratings created by EUV exposure
- AFM provides direct measurement of physical diffraction grating due to resist shrinkage during exposure
- This complementary information aids the interpretation of RSoXS scattering data

Future Goals

- Complete RSoXS measurements for a series of base loadings
- Complete AFM measurements
- Compare experimental data with modeled resist performance
- Explore the possibility of in-situ baking of resist in RSoXS experiment
- Explore in-situ development measurement via AFM

Acknowledgment
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