Understanding RLS limitations for EUV pre-production stages: "Impact of resist dissolution"

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Outline

- Background/Objectives
- Description of DRM methodology/approach
- Experimental results/discussion
- Future work
- Summary

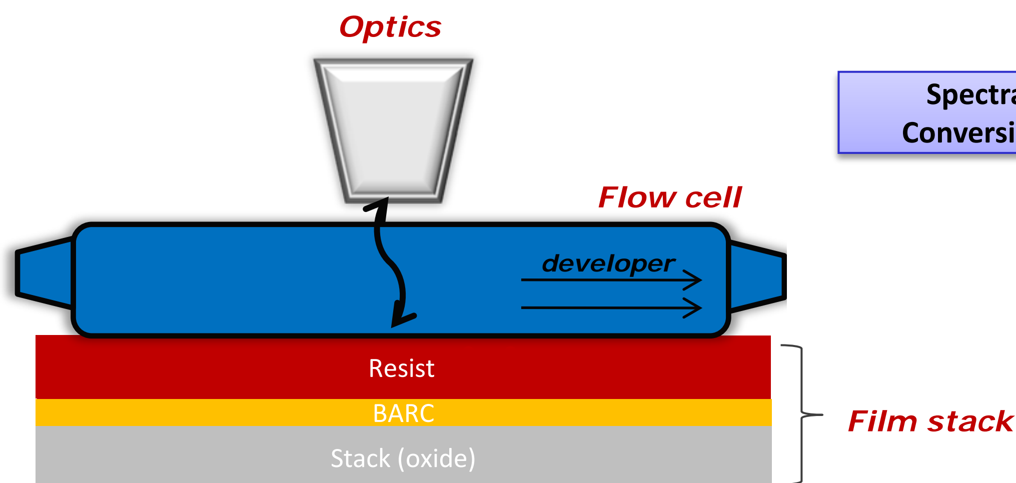
What is a DRM?

Stewart A. Robertson et. al, "Photoresist dissolution rates: a comparison of puddle, spray, and immersion processes", Proc. SPIE, Vol. 1464 (1991)

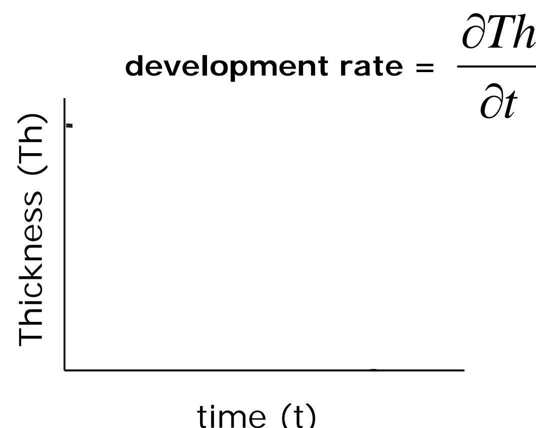
S. Scheer et. al, “Design of a cost-effective multiwavelength development rate monitoring tool”, Proc. SPIE Vol. 4689, (2002)

Development Rate Monitor

- Apparatus for in-situ thickness measurement thru time (Thickness vs. Time)
- A DRM can allow learning on development rates for different materials/process conditions
- DRM design impacts the learning on real development process/HW



Spectra Conversion

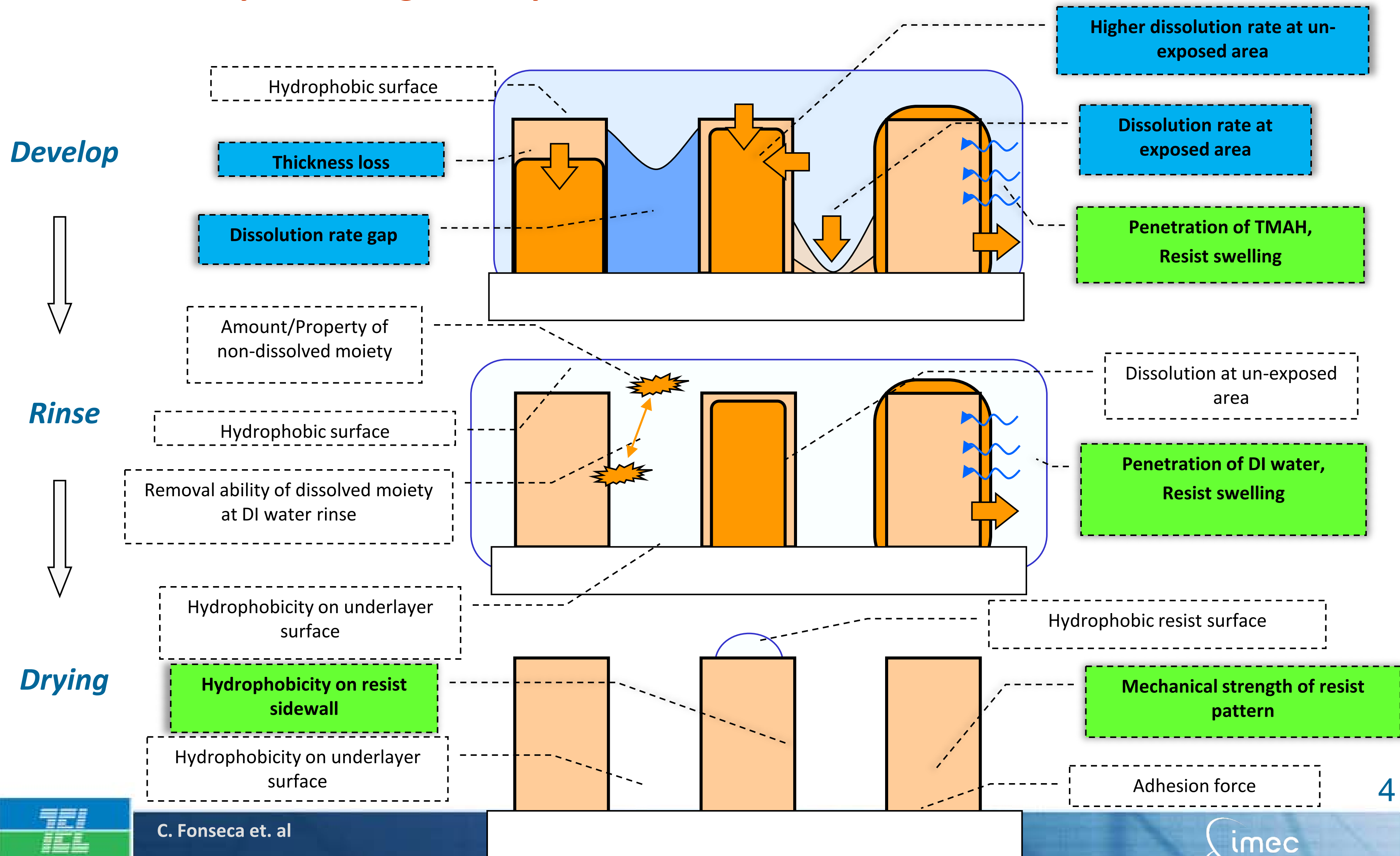


Background/Motivation

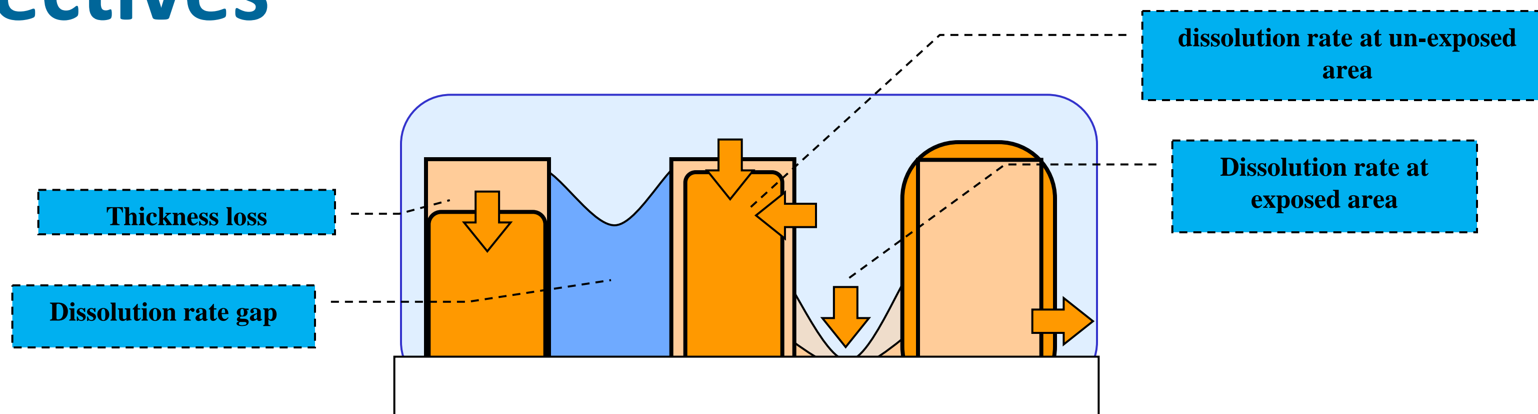
Contrast

Pattern collapse

Post PEB processing is complex!



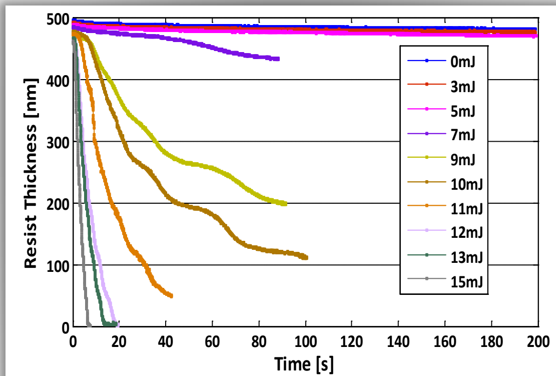
Objectives



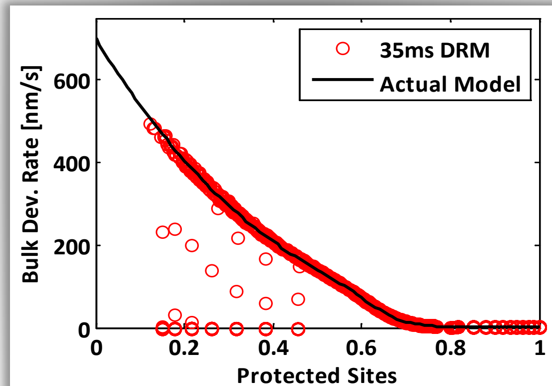
1. **Characterize EUV resist dissolution effects**
   - Quantify effects of process changes (ex: TBAH vs. TMAH)
   - Assess impact of material types on dissolution characteristics
2. **Use modeling techniques to understand impact of dissolution on RLS limitations**
   - Assess current limitation of EUV dissolution contrast
   - How much dissolution contrast is needed?
   - What if is the dissolution contrast could further be improved? How?

DRM modeling approach

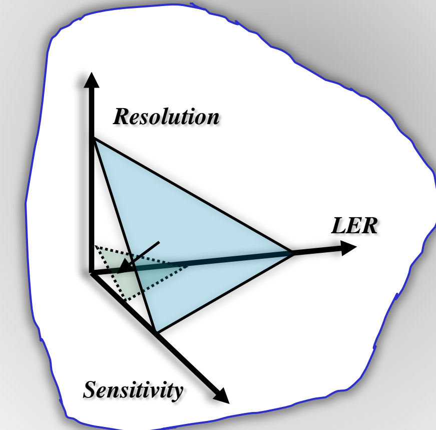
DRM Experimental Data



DRM dissolution Model creation



Simulation Study (impact of dissolution)



DRM data at various process conditions

Build "DRM Model" database

Use DRM models to predict impact on RLS trade-offs

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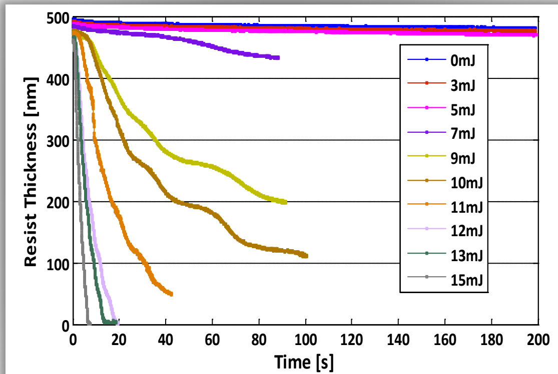
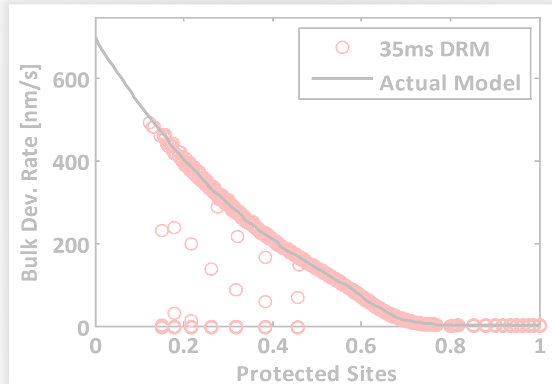
DRM modeling approach

DRM Experimental Data



DRM dissolution Model creation



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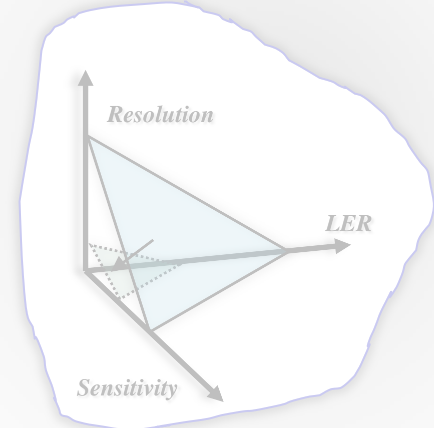
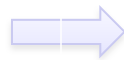


DRM data at various process conditions



Build "DRM Model" database

Use DRM models to predict impact on RLS trade-offs

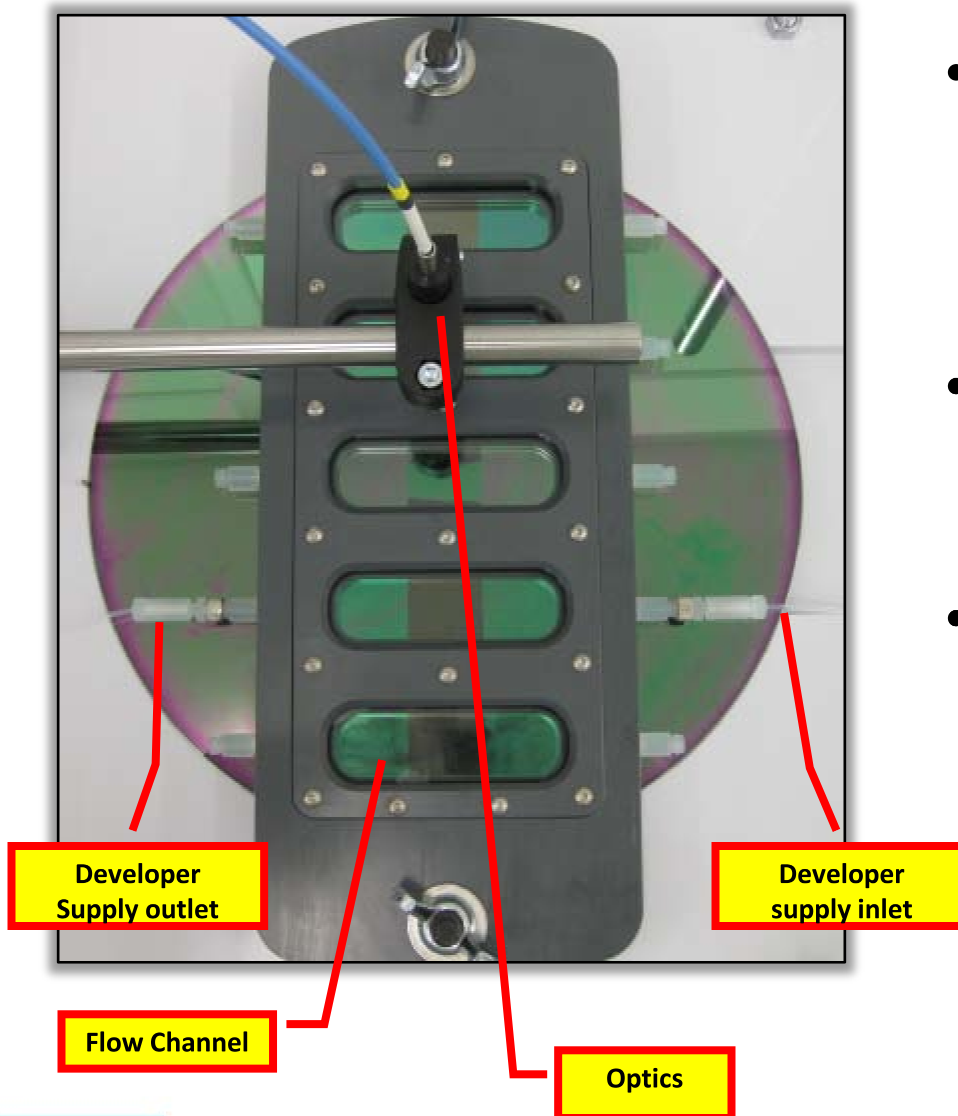
Experimental Conditions

Experimental Matrix

EUV Resist	Exposure λ	Developer	Purpose	Material Type
Resist A	EUV	TMAH	Baseline Process	Acrylate
Resist A	EUV	TBAH	TBAH effect	Acrylate
Resist B	EUV	TMAH	Material Type	Hybrid
Resist B	EUV	TBAH	TBAH effect	Hybrid

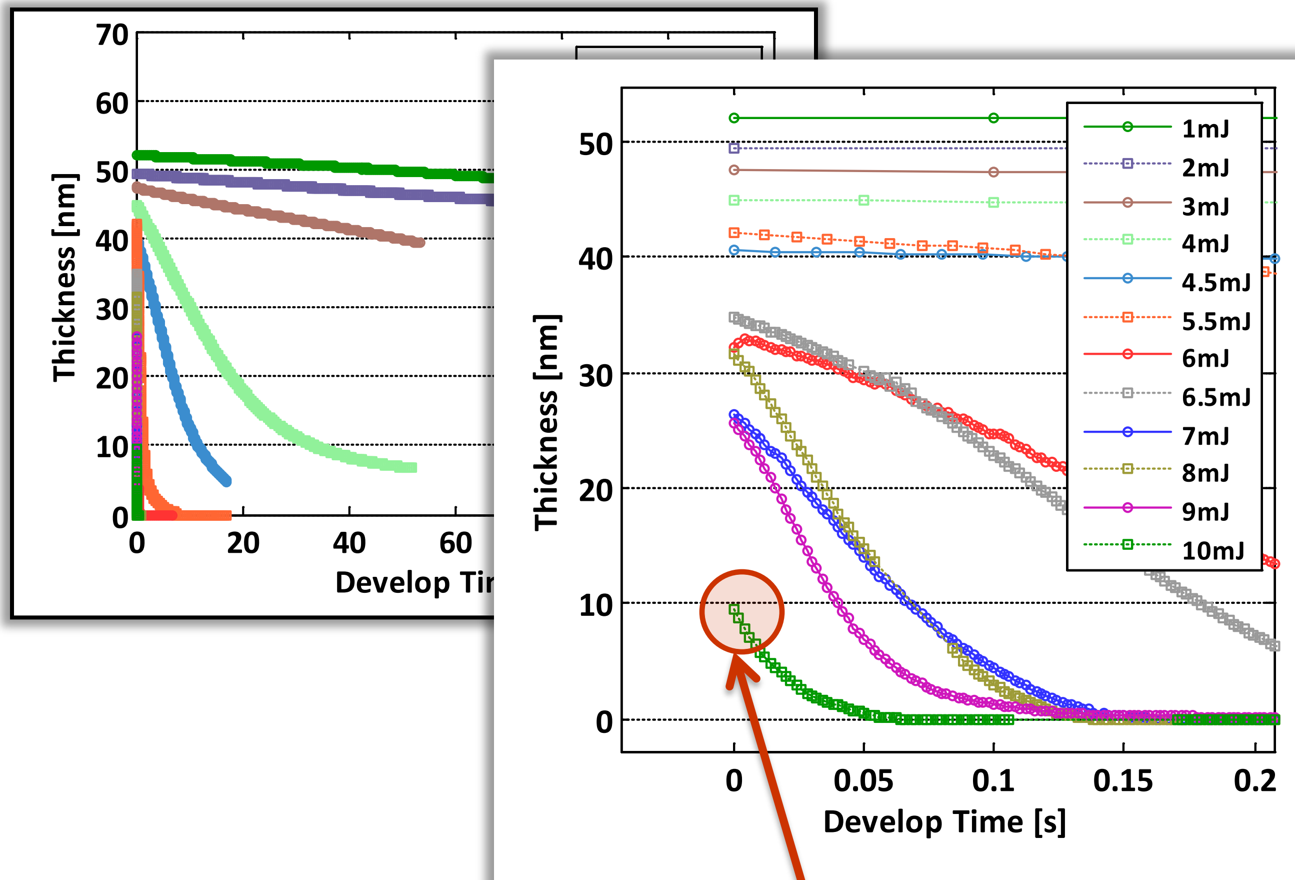
- **50nm resist thickness – Coating/PEB on TEL ACT™ 12**
- **EUV exposure: 0.25NA, 0.5σ**
- **EUV Stack: Si/Oxide (1μm)/BARC (20nm)**
- **Metrology (FT): SCD-100**
  - post-PEB film thickness (FTL) and contrast curve (CC) ← *Used for estimating de-protection kinetics*

DRM Setup



- **Flow cell design**
  - Allows 5 exposure fields per wafer
  - Flexibility in evaluating develop conditions
- **High acquisition time (2ms)**
  - Allows data mining for faster dissolution rates
- **Multiple wavelength optics**
  - Acquisition for ultra-thin films

Resist A (baseline process)

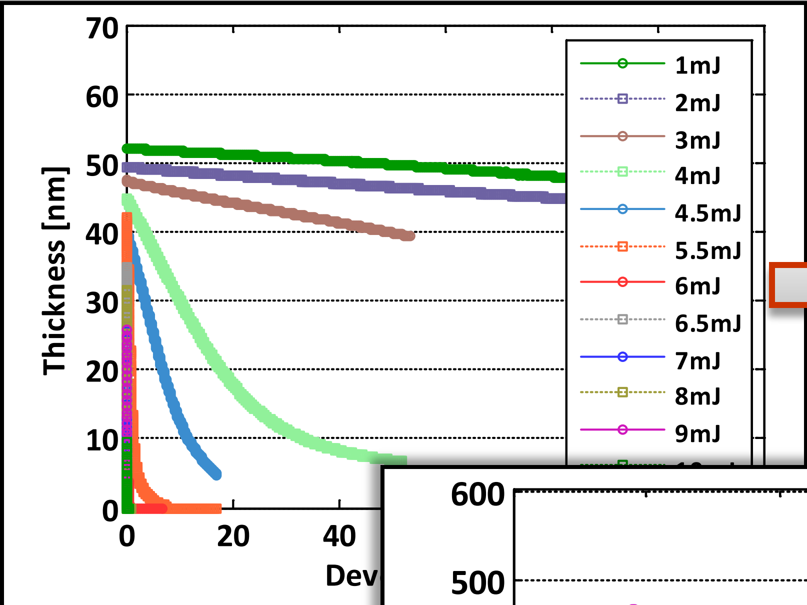


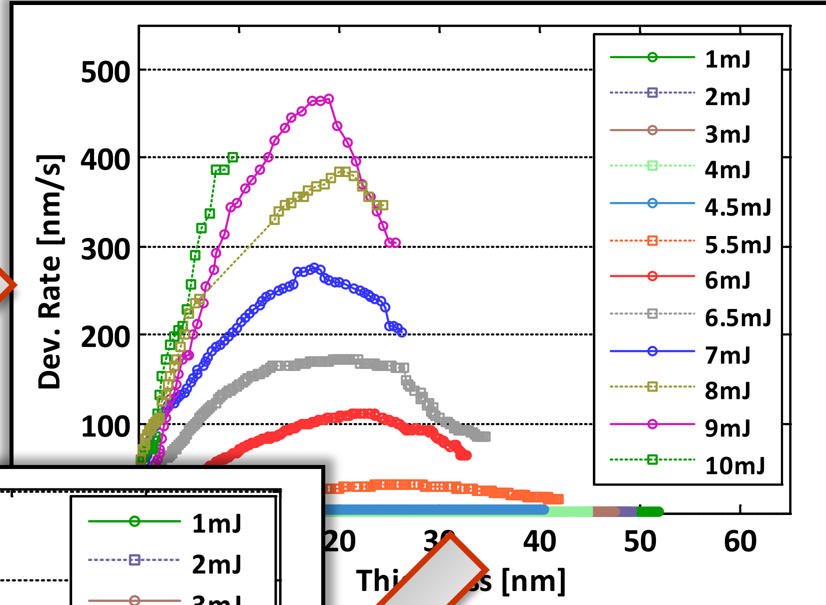
High acquisition (2ms) DRM allows for better sampling at higher dissolution rates

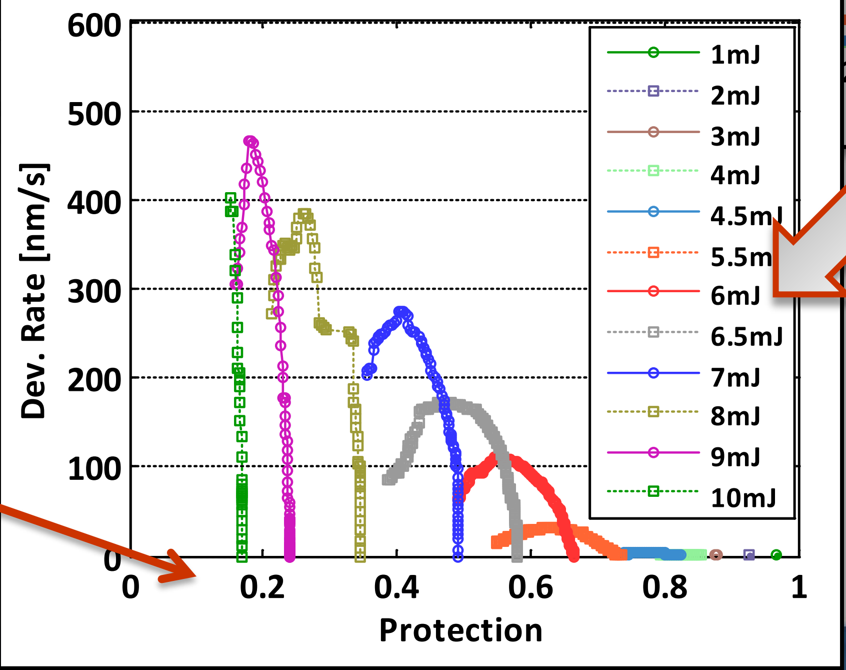
Meniscus travel time limits initial thickness
Travel time ~100ms
(t=0s defined as time after meniscus passes)

Resist A, EUV exposed, TMAH

Resist A (baseline process)

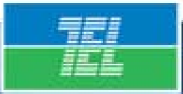






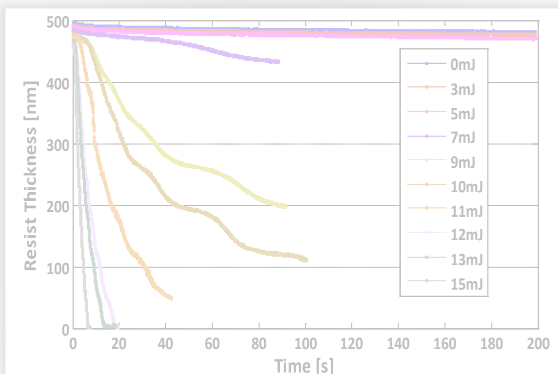
Polymer protection is estimated from FTL and CC data

FTIR measurement potental



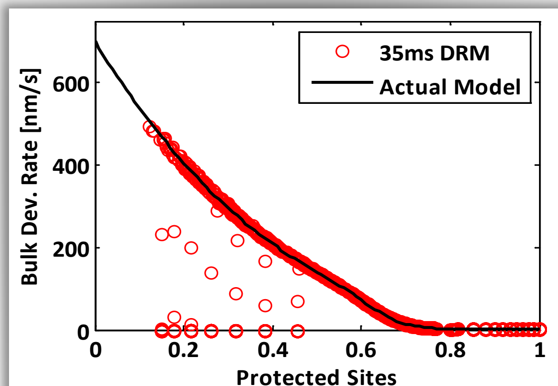
DRM modeling approach

DRM Experimental Data



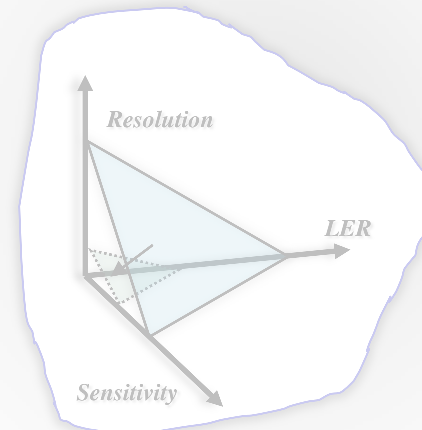
DRM data at various process conditions

DRM dissolution Model creation



Build "DRM Model" database

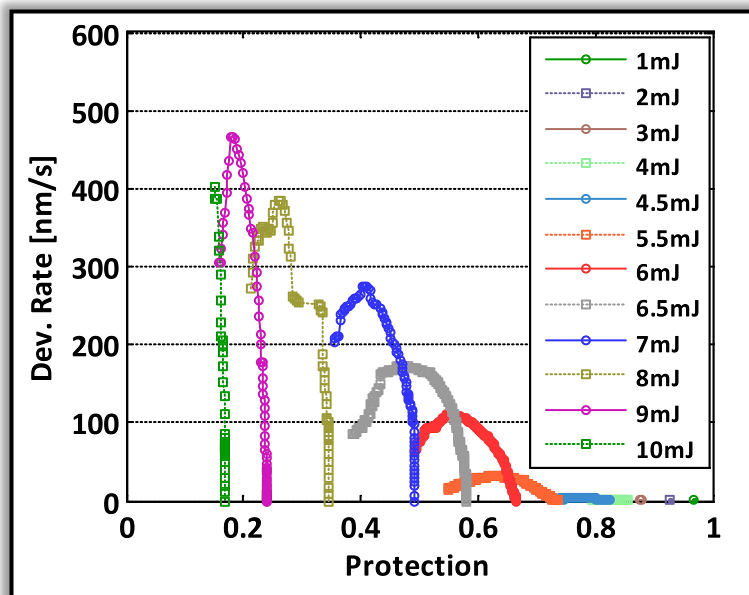
Simulation Study (impact of dissolution)

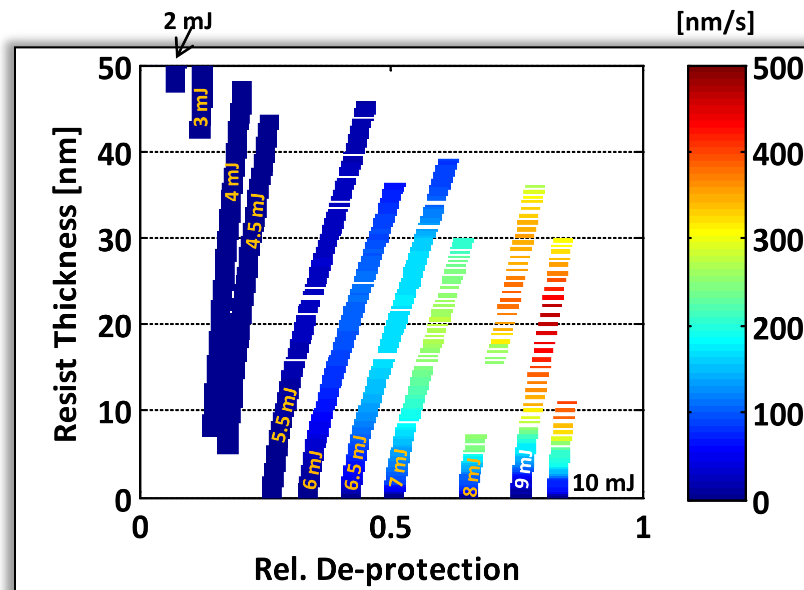


Use DRM models to predict impact on RLS trade-offs

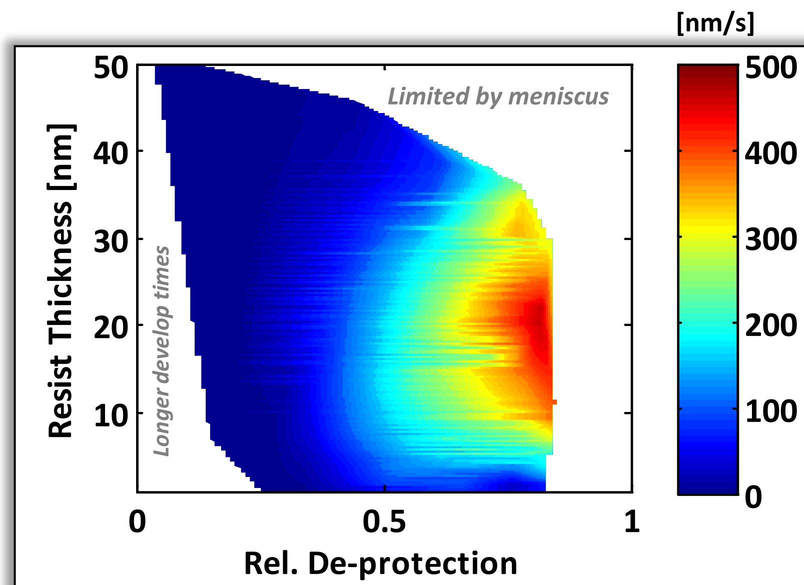
Resist A, EUV exposed, TMAH

Creation of "DRM Model"

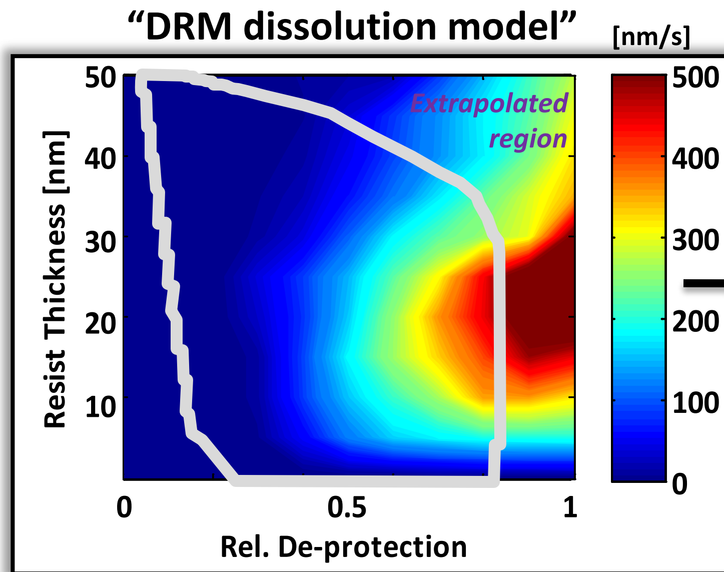


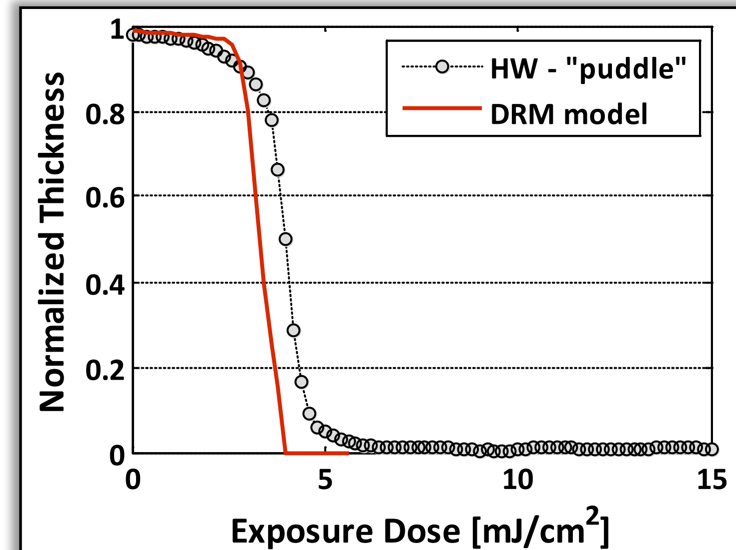


This information could be used in lithography simulators for a more accurate representation of the dissolution characteristics



DRM dissolution vs. HW (track) dissolution





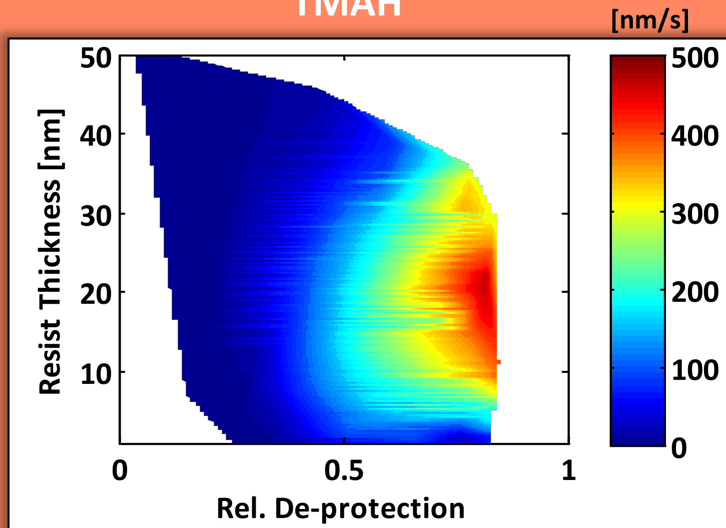
- **DRM dissolution varies from HW dissolution**
  - Expected result
  - DRM process is likely more dynamic (low constant flow)
- **Relative comparisons are still valid**

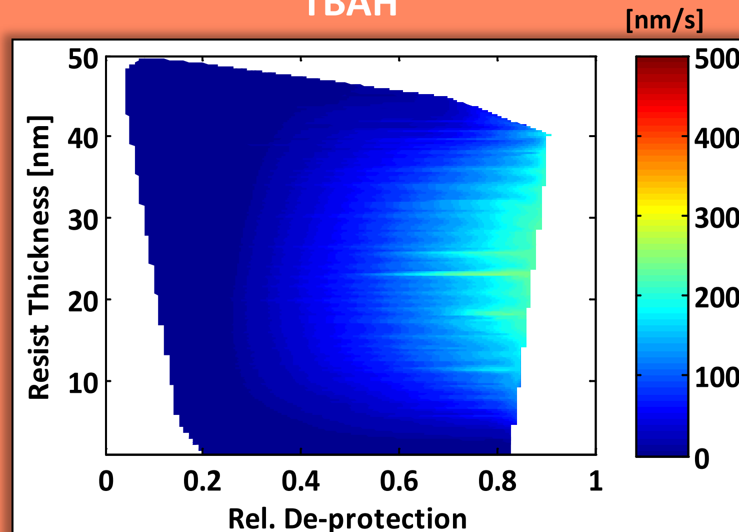
Summary of dissolution effects

TMAH

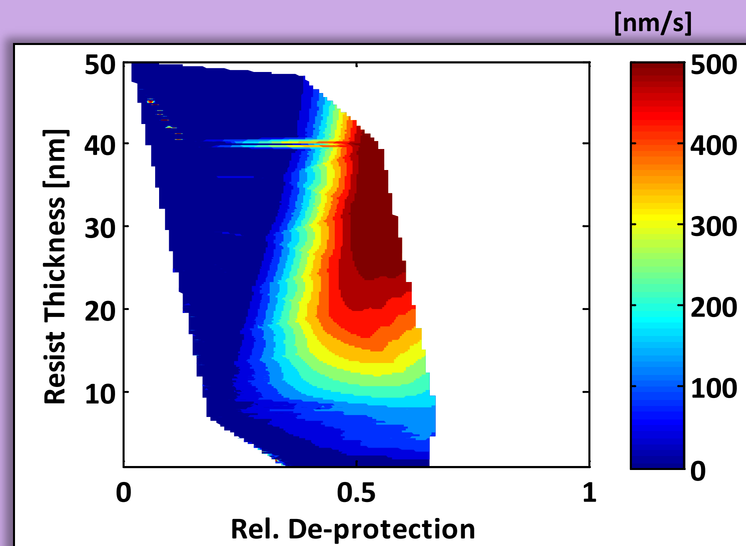
TBAH

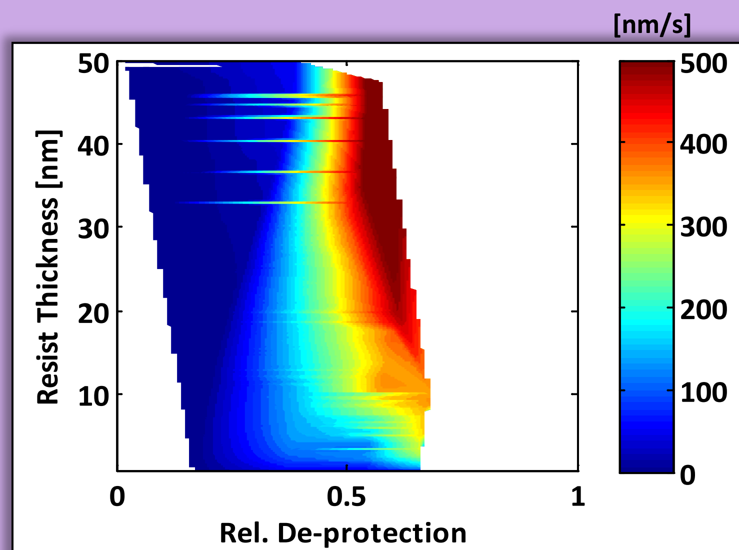
Resist A, EUV exposed





Resist B, EUV exposed





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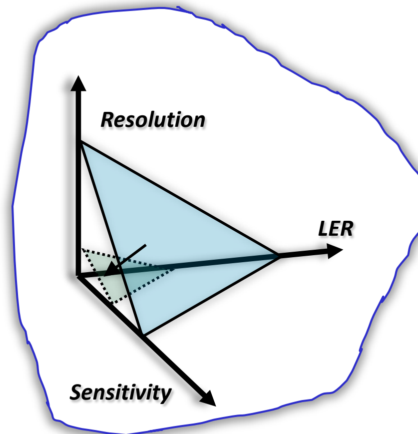
Observations

Observation	Significance	Comments
Resist dissolution varies across film thickness (EUV)	- Slower dissolution rate at bottom 10-15nm - May have impact on resist profile, LWR, resolution	- De-protection varies across thickness - Vertical gradients of species (PAG/quencher) - EUV specific?
Opposite trends observed with TBAH development with resist A and B	TBAH impact on dissolution is resist platform dependent (EUV)	Opposite trends should be observed with printed CD data
No evidence of swelling with EUV exposures	- Previous reports: swelling may exist - DRM cannot detect (if present)	Swelling may be present during meniscus passing – cannot measure during passing
Resist polymer type could have significant impact on dissolution	- Impact on defect formation (more or less prone) - Impact on developer sensitivity	-

Future Work

- **Complete database of "DRM models"**
  - Define final format for lithography simulator
- **Simulations of RLS trade-offs given a set of DRM models (SPIE 2011)**
  - Assess impact of current dissolution characteristics on resolution, sensitivity and (possibly) LER
  - Sensitivity analysis of process perturbations (ie, dissolution contrast changes)

Simulation Study (impact of dissolution)



Summary

- **A “DRM” analysis methodology was presented**
  - Dissolution rates for ultra-thin resist films (50nm) was demonstrated
  - Creation of dissolution model from DRM data
- **Initial DRM data suggests:**
  - Impact of TBAH developer on dissolution is resist platform dependent
  - Slower dissolution observed at bottom 10-15nm resist thickness
- **A DRM model can potentially provide a better description of the dissolution characteristic for lithography simulations**
- **Future work will investigate the impact of EUV dissolution properties on RLS limitations**
  - Simulation study with “DRM models”

Acknowledgments

- **TEL**
  - Neil Bradon, Ben Rathsack and Steven Scheer
- **IMEC**
  - Philippe Foubert

Thank you for your attention!