Characterization of a NCA resist for photomask fabrication using 257 nm Optical Pattern Generation

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257 nm Optical Pattern Generation

- Resolution
  - OPC
  - Phase shifting
- Non-chemically amplified resist
  - Post coat delay
  - Post exposure delay
  - No PEB facilities
  - Cluster tool mini environment

$$R = k_1 \frac{l}{NA}$$

Non Chemically Amplified Resist Development at 257 nm

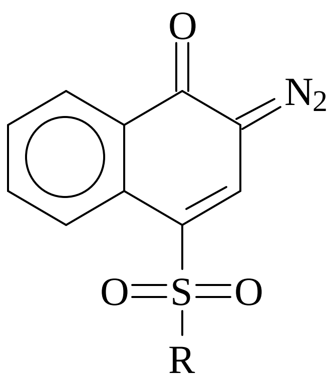
Goal: Develop a **bleachable** and **inhibiting** NCA resist at 257 nm

Method: Screen existing resist materials

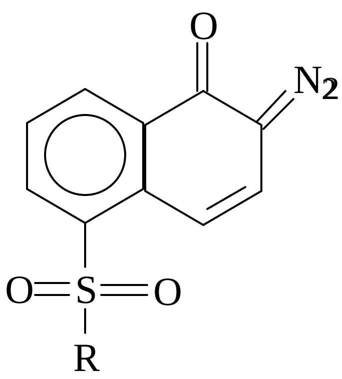
Process: Resist characterization, simulation and formulation

DNQ/ Novolak Materials

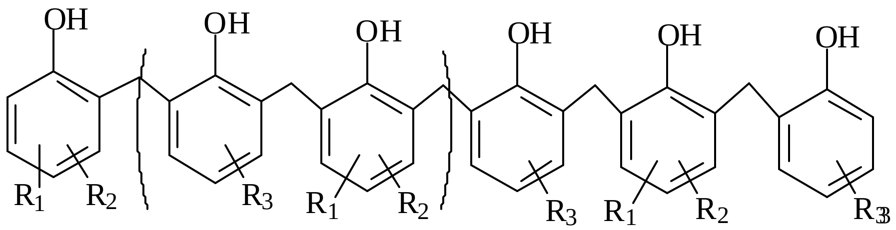
2,1,4 DNQ



2,1,5 DNQ



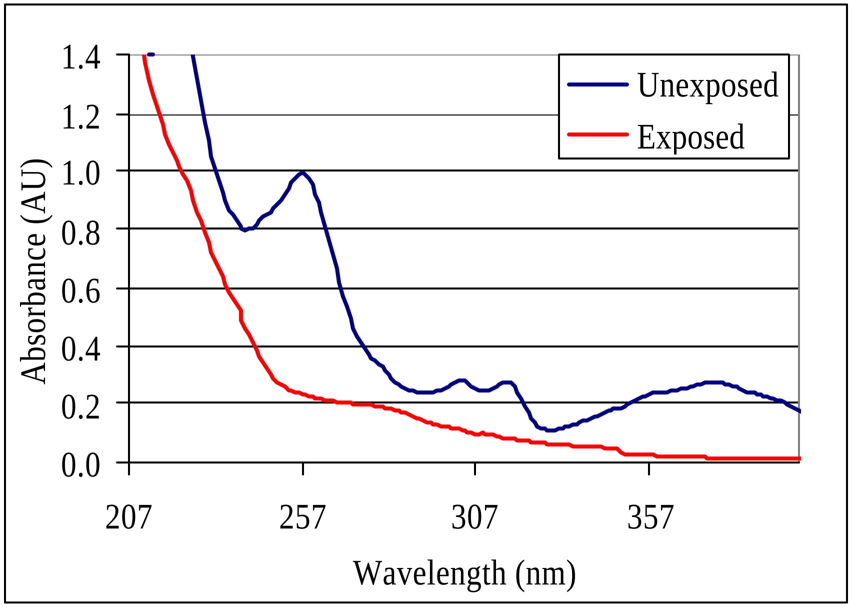
Novolak



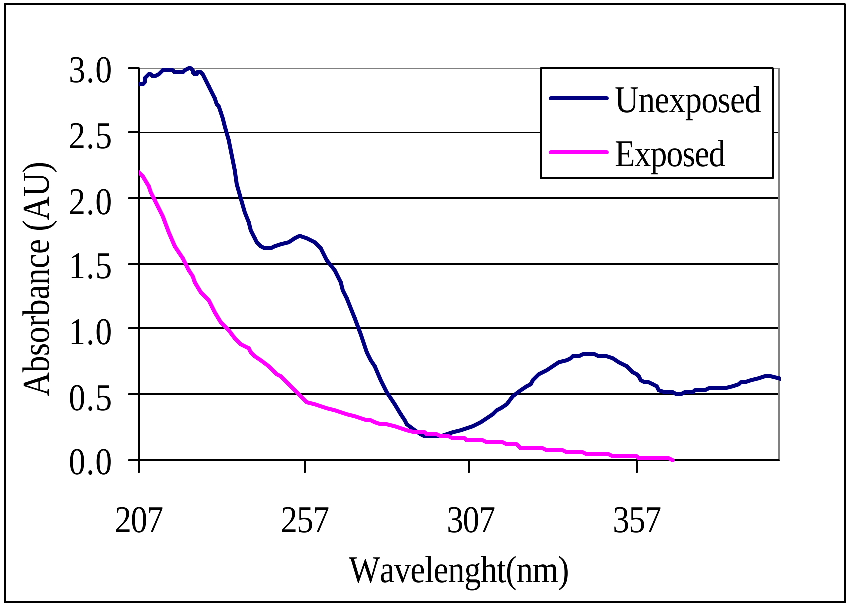
PAC Bleaching Properties

- 2,1,4 DNQ bleaches more than the 2,1,5 DNQ at 257 nm

2,1,4 DNQ

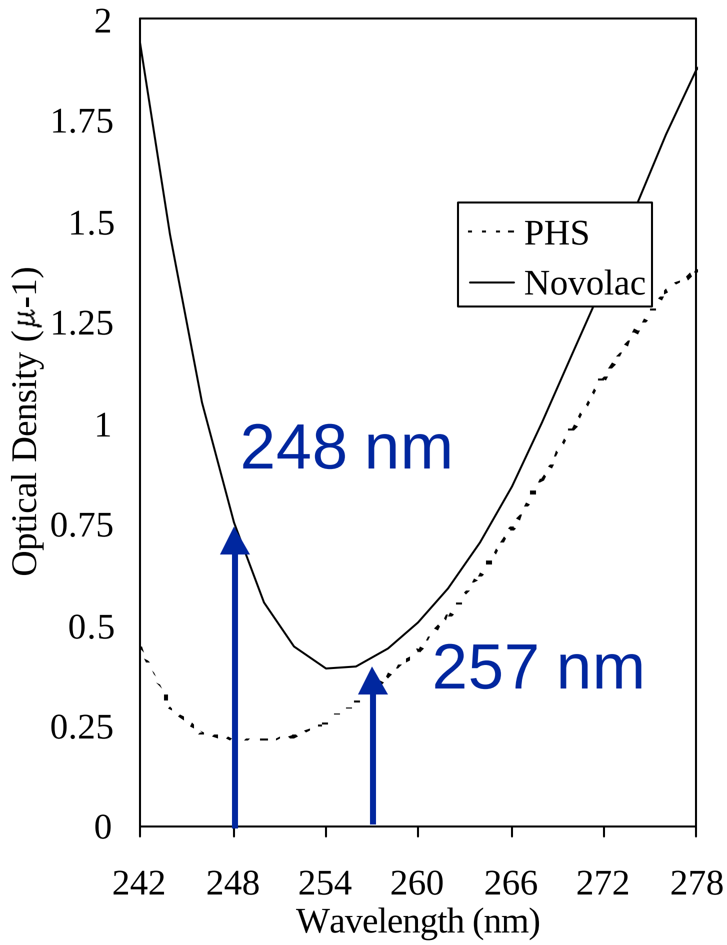


2,1,5 DNQ



Novolak vs PHS Absorption

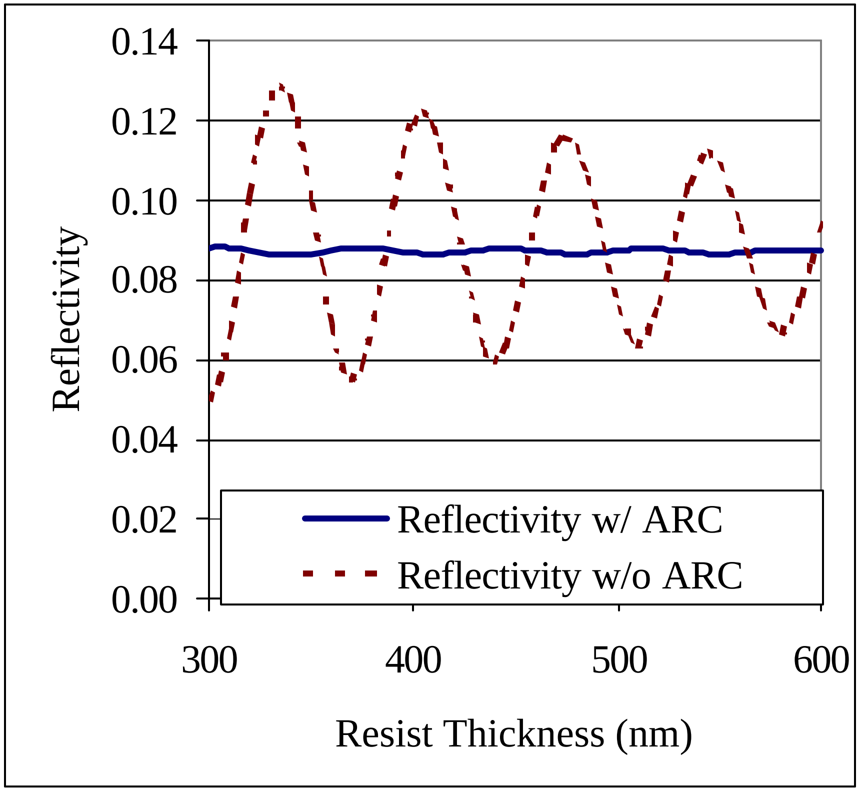
- Novolak absorption is similar PHS at 257nm



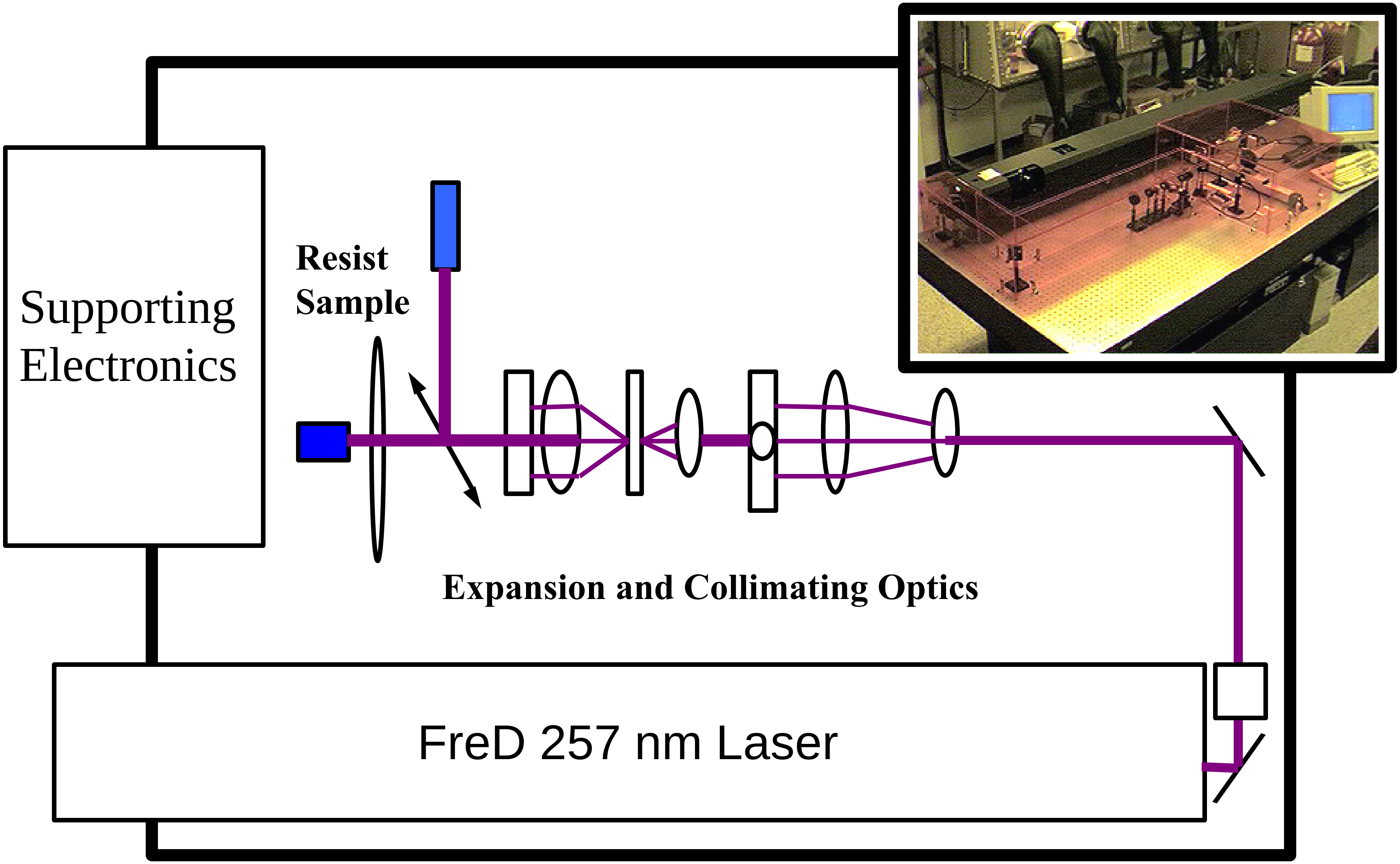
Resist Swing Curves

- Simulated reflectivity minimum at a resist thickness of 440 nm or 370 nm

- Organic antireflection coating minimizes standing waves and the swing ratio at a film thickness of 50 nm

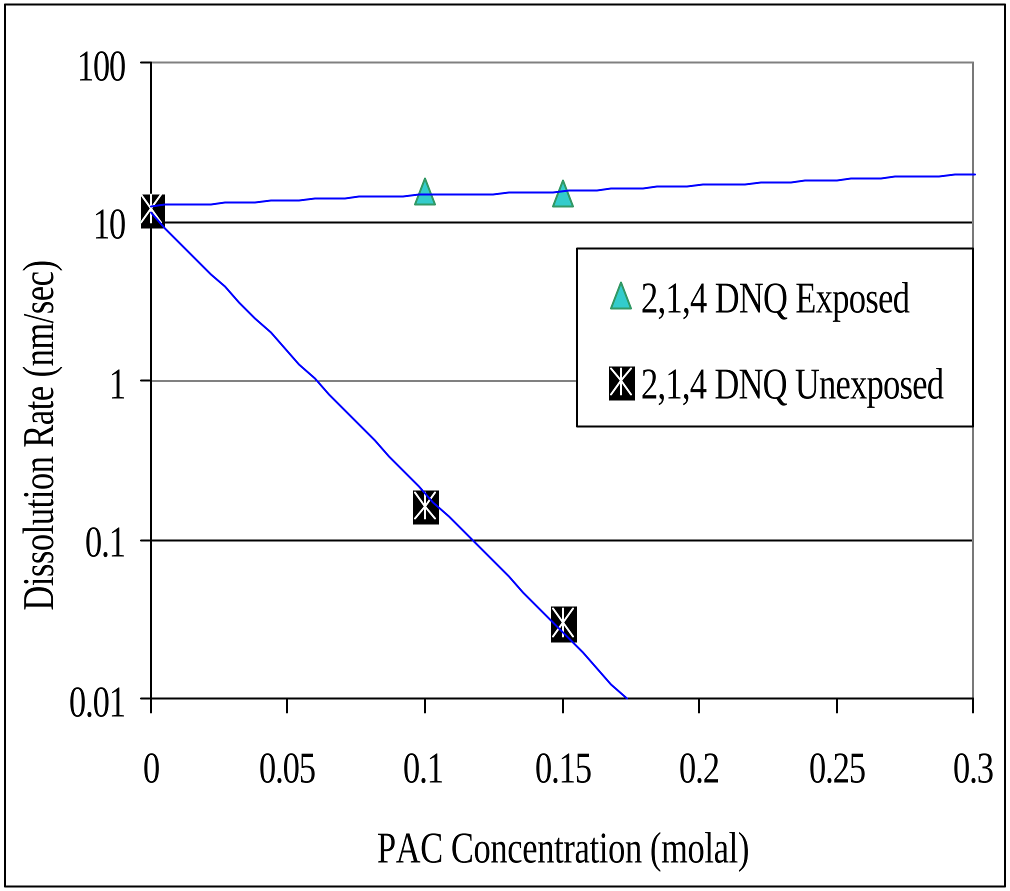


Photoresist Exposure Tool



NCA Resist Dissolution Properties

- 2,1,4 DNQ is a strong inhibitor in 0.26 N TMAH (TOK NMD-W)



Film Thickness is 440 nm /300 second PAB at 90 °C/No PEB

Lithographic Modeling Equations

- Image transfer is dependent on the absorption (α) of the resist

$$\frac{\partial I(x,t)}{dz} = -I(x,t)\alpha(x,t)$$

- Low absorption improves image transfer

$$\alpha = Am + B$$

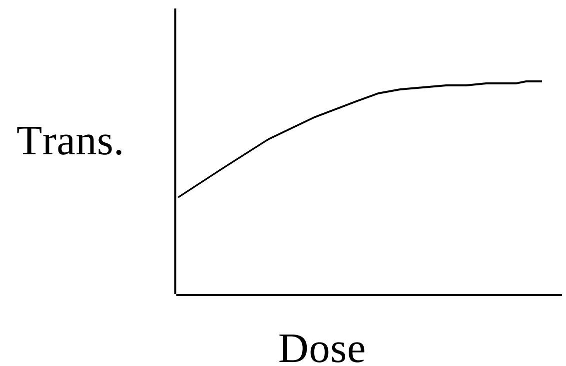
Dill Exposure Equations (Ellipsometry)

- A = bleachable absorbance (μm^{-1})

$$A = \frac{4p(k_2 - k_1)}{l}$$

- B = unbleachable absorbance (μm^{-1})

$$B = \frac{4pk_1}{l}$$



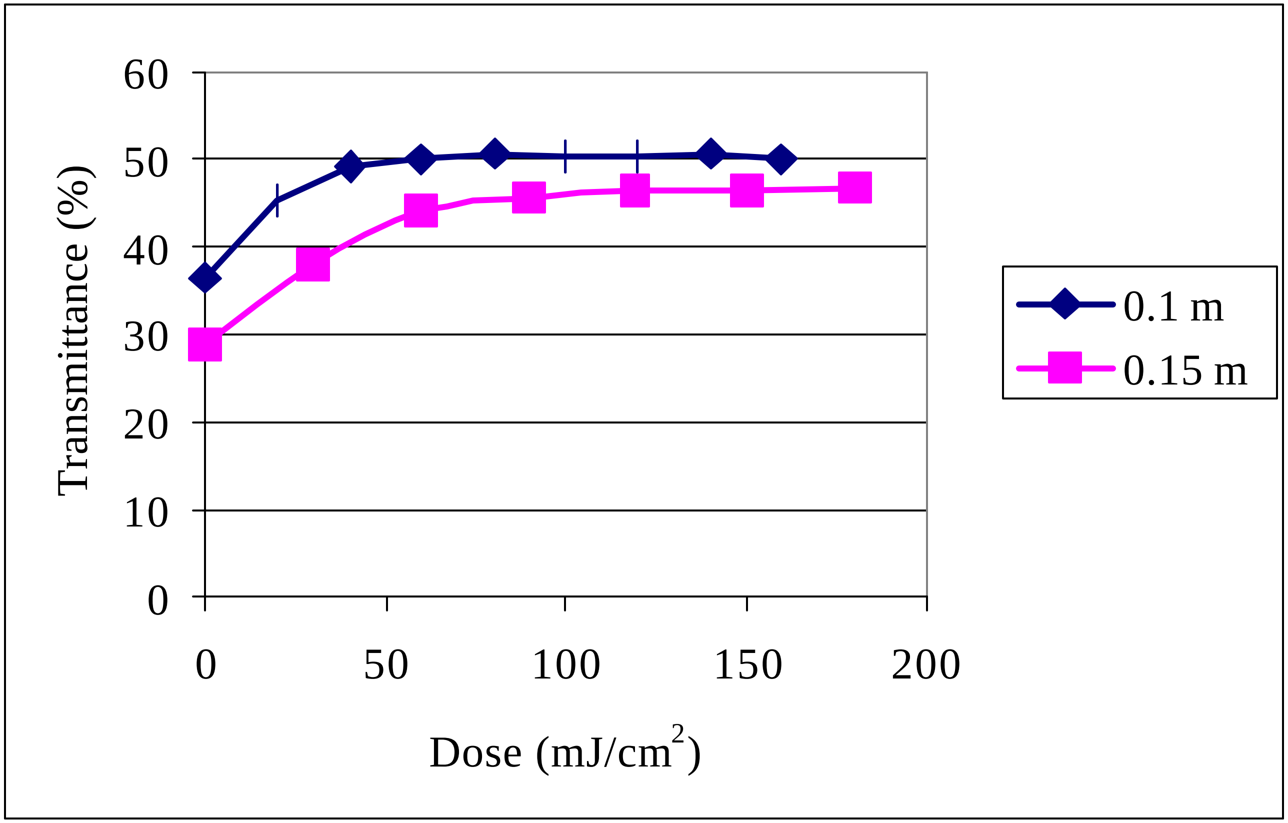
- C = rate constant of PAC conversion (cm^2/mJ)

$$C = \left(\frac{A+B}{A}\right)\left(\frac{1}{T(0)\{1-T(0)\}}\right)\left(\frac{dT(0)}{dE}\right)$$

k_1 = exposed complex index of refraction
k_2 = unexposed complex index of refraction

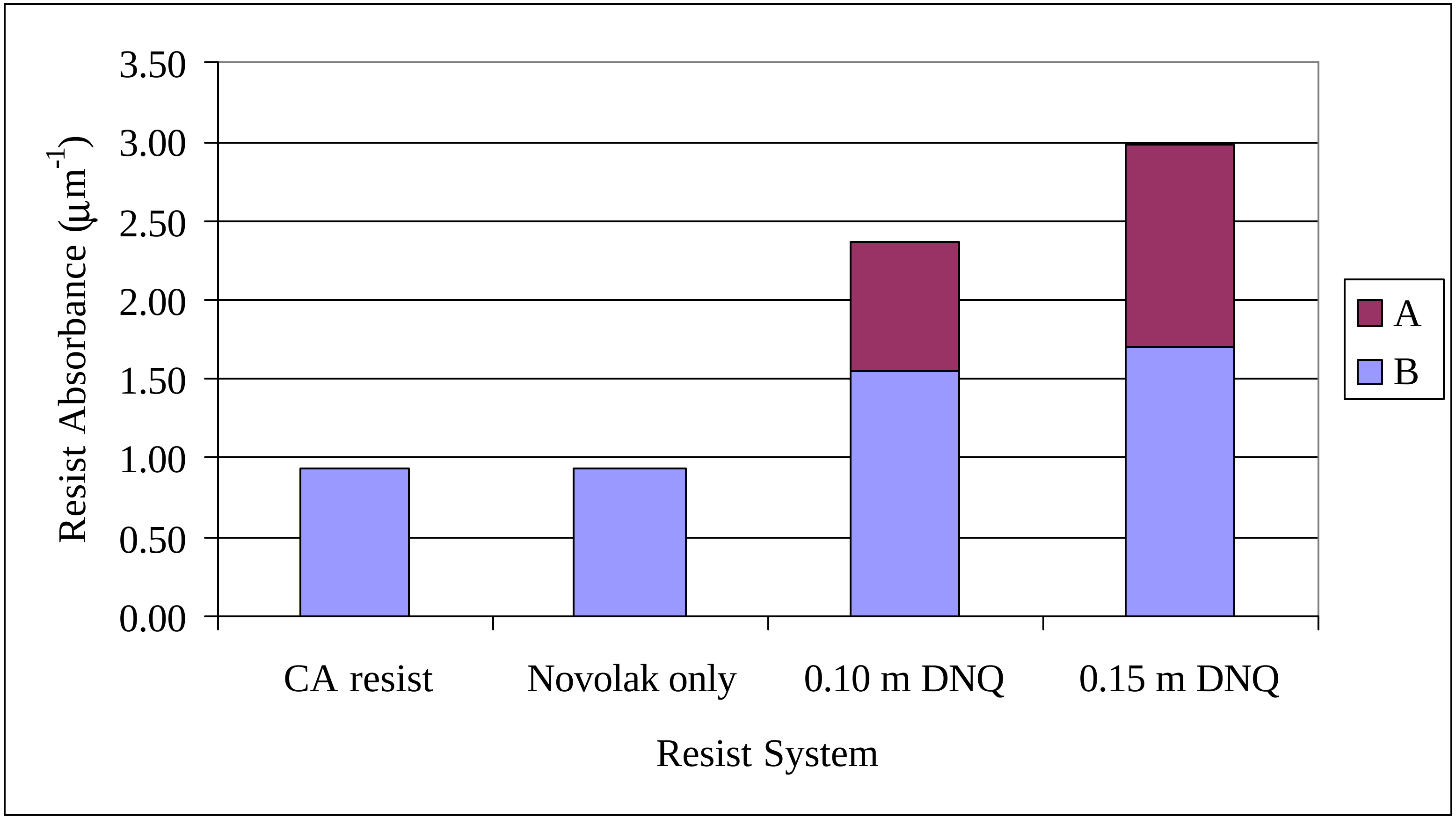
PAC Bleaching Properties

- 2,1,4 DNQ (0.1 molal) bleaches with a high photospeed
- Exposure rate constant (C) equals 0.04 cm^2/mJ



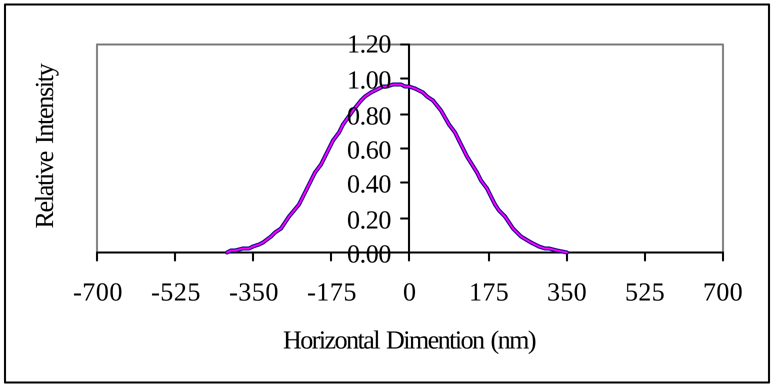
Dill's Exposure Parameters

- Lower PAC concentration provides less absorbance of the NCA resists
- CA resist has less absorbance than NCA resists at 257 nm

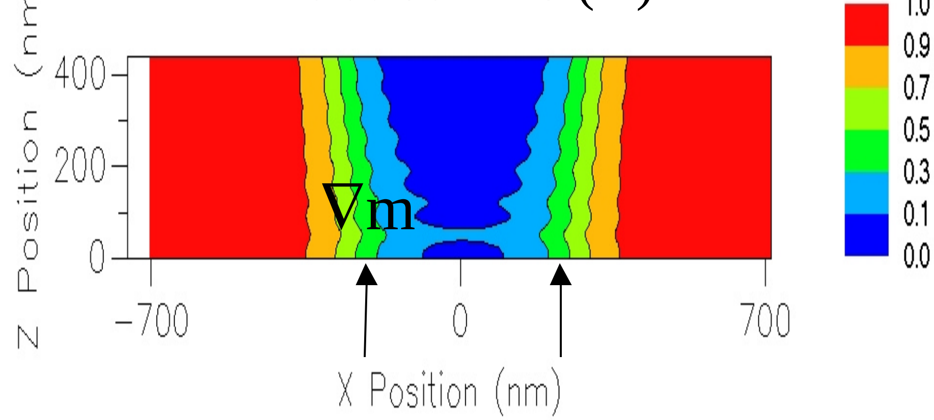


Resist Formulation through Simulation

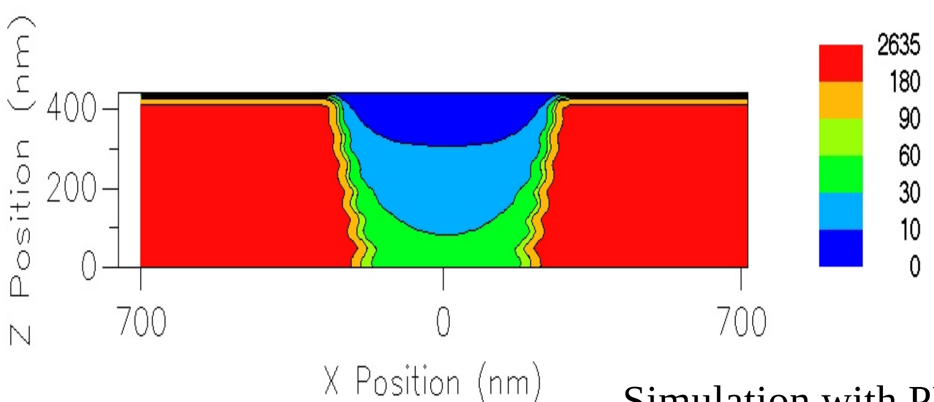
Aerial Image



Relative PAC (m)

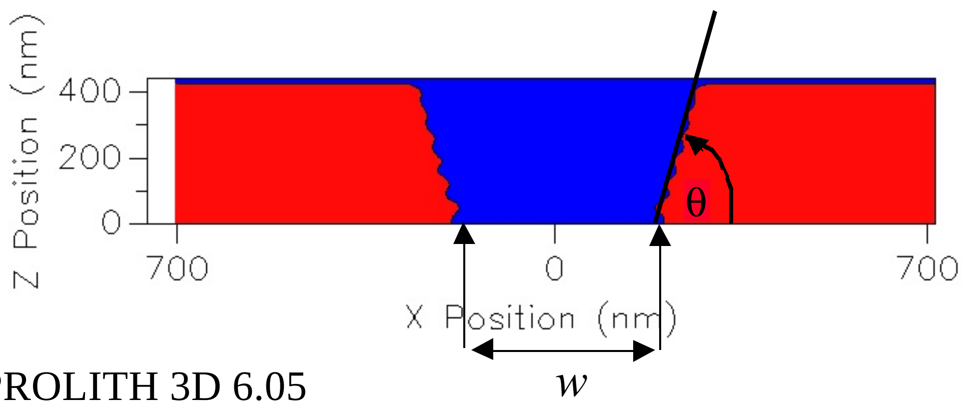


Develop Time Contours



Output: Resist Profile

Sidewall angle θ and feature size *w*



Simulation with PROLITH 3D 6.05

Lithographic Imaging Equation

High Resolution Imaging

1. Image Transfer
Position steepest slope (inflection point) of the aerial image at the feature edge

2. Dissolution contrast (γ_R)
Maximize dissolution change with dose through R(m) analysis

3. Dissolution Threshold
Position dissolution threshold at the inflection point of the image

1-Dimensional Analysis

$$\left.\frac{dR}{dx}\right|_{x^*} = g_R \frac{dm}{dx}$$

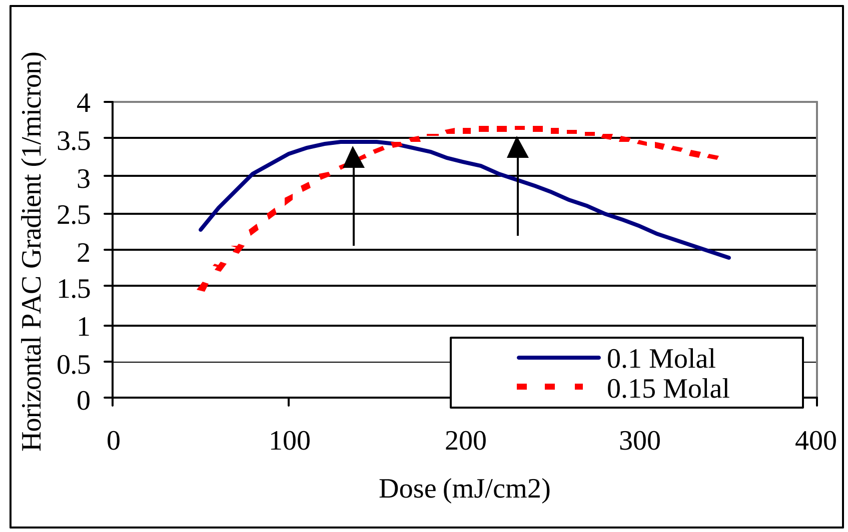
$$g_R = \frac{dR}{dm}$$

R = Dissolution rate
x = Horizontal position
m = Relative PAC Concentration
g_R = Resist contrast
x^* = Nominal edge of resist feature

Simulated Optimum Exposure Dose for Photomask Lithography

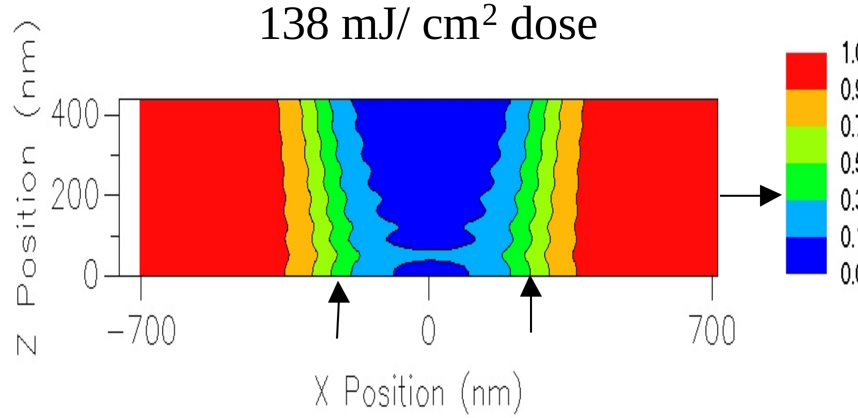
Best Doses for Image Transfer

DNQ (0.1 molal) ≅ 138 mJ/cm^2
DNQ (0.15 molal) ≅ 225 mJ/cm^2



Maximum PAC gradient at the feature edge

m(x,z) of DNQ (0.1 molal)/ Novolak at 138 mJ/ cm^2 dose

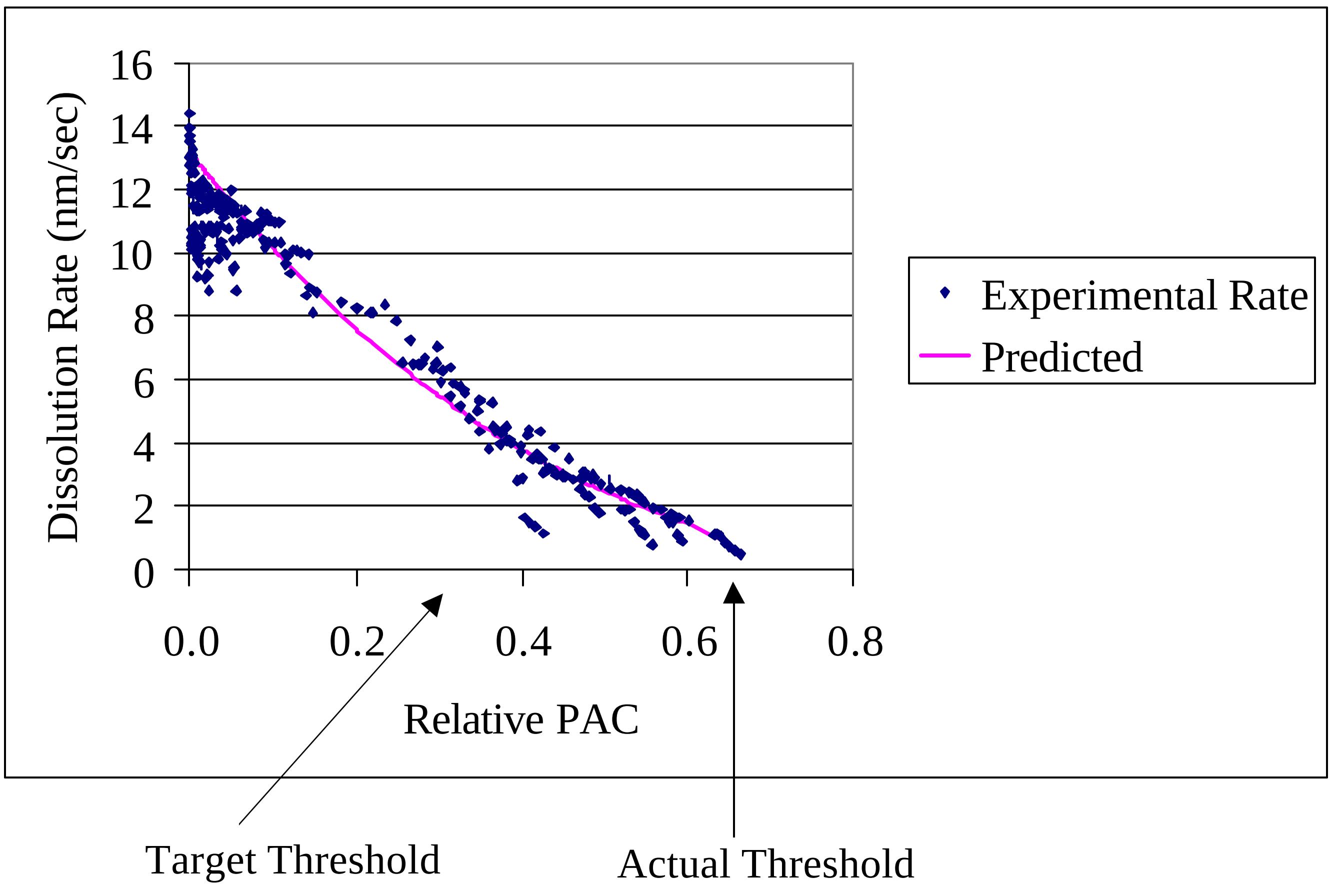


<u>Target m</u>

DNQ (0.10 molal) = 0.3
DNQ (0.15 molal) = 0.3

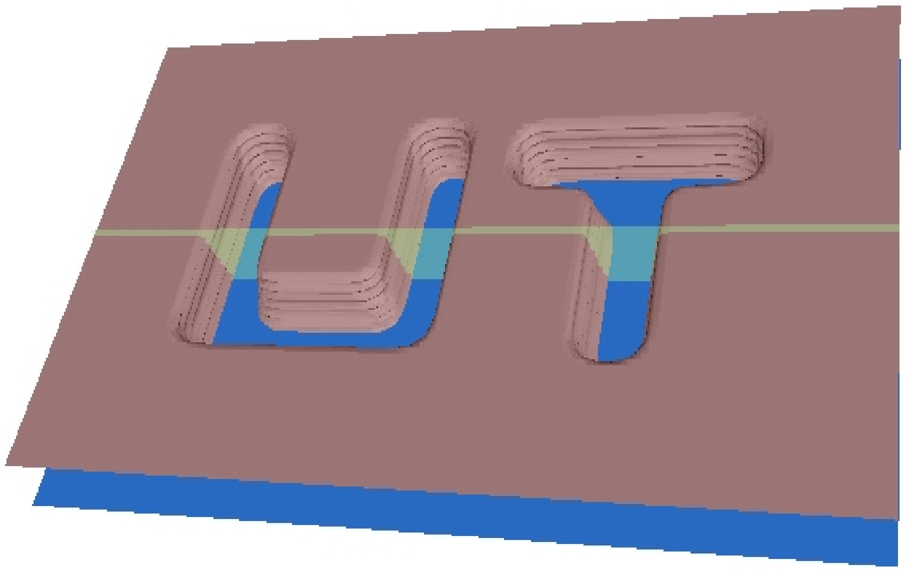
Development Rate Analysis

- Lower Developer concentration (<0.26 N TMAH) is needed to maximize resolution and process latitude



Summary

- DNQ/ Novolak Resists are a viable option at 257 nm



2,1,4 DNQ (0.1 molal)/ Thickness 440 nm/ 300 sec 90 °C PAB

Simulation with PROLITH 3D 6.05

Future

- Use simulation to optimize 257 nm NCA resist process
  - Developer Concentration
  - Lower Absorbance
- Standing wave reduction
  - Post-exposure bake
  - Organic antireflection materials
- Study CA resist in mask making environment
  - Latent image stability
  - Coated resist stability

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