CHE323/CHE384
Chemical Processes for Micro- and Nanofabrication
www.lithoguru.com/scientist/CHE323

Lecture 52
Lithography: Chemically Amplified Resists, part 2

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Simple CAR Model

- If h is locally constant,

$$h = 1 - e^{-CIt}$$

$$m = e^{-\alpha_f h}$$

$$h = \frac{H}{G_o} \qquad m = \frac{M}{M_o}$$

where $K_{amp} = G_o k_4$ = normalized rate constant
$\alpha_f = K_{amp} t_{PEB}$ = amplification factor

Chemically Amplified Resists

- There is a trade-off between exposure dose (which generates more acid) and thermal dose (which causes more amplification for a given amount of acid)

$$h = 1 - e^{-CIt} \qquad m = e^{-\alpha_f h}$$

- The optimum trade-off is determined by acid diffusion and acid loss mechanisms

Acid Diffusion

- Diffusion of the acid complicates the solution to the kinetic equations.

$$\frac{\partial H}{\partial t} = \frac{\partial}{\partial z}\left(D_H \frac{\partial H}{\partial z}\right) \quad \text{(1D diffusion equation)}$$

where D_H = diffusivity of acid in the polymer

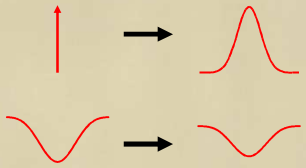
$$\frac{\partial H}{\partial t} = \nabla(D_H \nabla H) \quad \text{(3D diffusion equation)}$$

PEB Diffusion

- Diffusion is a convolution of the latent image with the *DPSF* [h*(x) = after-bake latent image]:

$$h^*(x) = h(x) \otimes DPSF$$

Gaussian function



Reaction-Diffusion

- Because of diffusion, *h* is not locally constant

$$h_{eff}(x) = \frac{1}{t_{PEB}} \int_0^{t_{PEB}} h(x, t=0) \otimes DPSF \, dt$$

Deblocking responds to the time-average of the acid concentration, h_{eff}

$$m(x) = e^{-\alpha_f h_{eff}(x)}$$

Reaction-Diffusion Point Spread Function

$$RDPSF = \frac{1}{t_{PEB}} \int_0^{t_{PEB}} DPSF\, dt$$

In 1D: $$RDPSF(x) = 2\frac{e^{-x^2/2\sigma_D{}^2}}{\sqrt{2\pi}\sigma_D} - \frac{|x|}{\sigma_D{}^2} erfc\left(\frac{|x|}{\sqrt{2}\,\sigma_D}\right)$$

Diffusion Length

$$\sigma_D = \sqrt{2Dt_{PEB}}$$

$$h_{eff}(x) = h(x, t=0) \otimes RDPSF$$

$$m(x) = e^{-\alpha_f h_{eff}(x)}$$

Acid Loss

- Acid is lost due to a variety of possible mechanisms:
  - evaporation from top of resist
  - base contamination from the substrate
  - bulk acid loss (trapping site in the resist)
  - diffusion of airborne base contaminants
- Sometimes, we purposely induce acid loss by adding a base quencher

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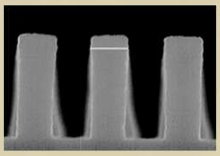
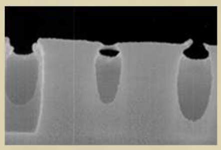
Atmospheric Contamination



0.275 µm features, no delay



0.325 µm features, 10 minute delay

APEX-E Resist
PAB: 100°C/60s, PEB: 90°C/60s
Development: 84s, MF702
Exposure: 4.28 mJ/cm²

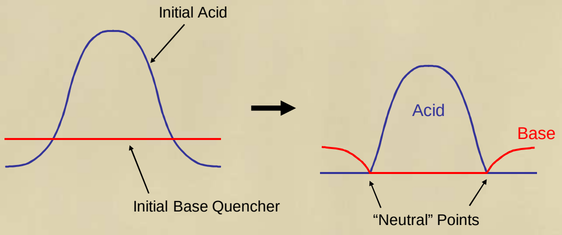
Courtesy of SEMATECH

T-Top Reduction

- Reduce post-exposure delay
  - Link track and stepper
- Reduce airborne base
  - Eliminate sources of contamination
  - Filter air in track and stepper
- Reduce diffusion of base into resist
  - Anneal resist during PAB
  - Use top coat (not preferred)

Base Quencher and Base Diffusion

- Base quencher is used to neutralize the acid generated by exposure



- Base quencher diffusion (relative to acid or aerial image diffusion) can move the "neutral" point

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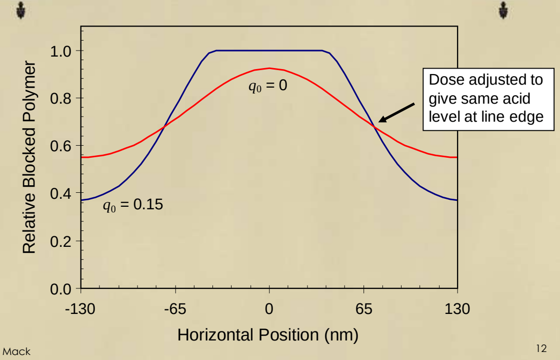
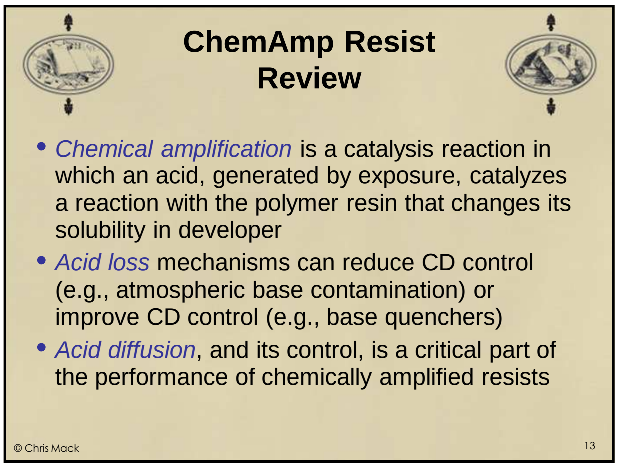
Impact of Quencher

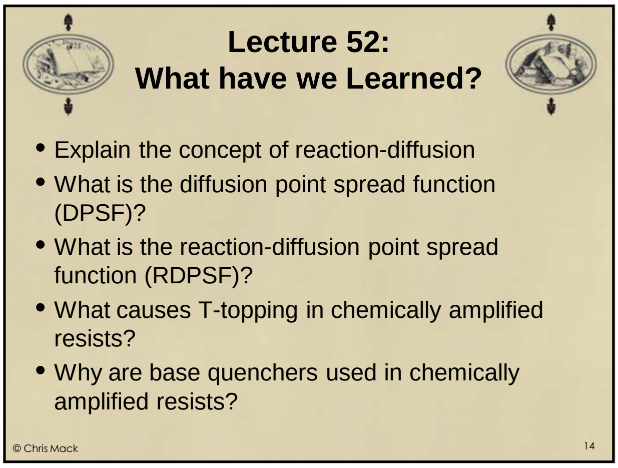


Dose adjusted to give same acid level at line edge



ChemAmp Resist Review

- *Chemical amplification* is a catalysis reaction in which an acid, generated by exposure, catalyzes a reaction with the polymer resin that changes its solubility in developer
- *Acid loss* mechanisms can reduce CD control (e.g., atmospheric base contamination) or improve CD control (e.g., base quenchers)
- *Acid diffusion*, and its control, is a critical part of the performance of chemically amplified resists



Lecture 52:
What have we Learned?

- Explain the concept of reaction-diffusion
- What is the diffusion point spread function (DPSF)?
- What is the reaction-diffusion point spread function (RDPSF)?
- What causes T-topping in chemically amplified resists?
- Why are base quenchers used in chemically amplified resists?