Lecture 52
Lithography:
Chemically Amplified
Resists, part 2
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Simple CAR Model
- If \( h \) is locally constant,
  \[ h = 1 - e^{-C \phi h} \]
  \[ m = e^{-\alpha_f h} \]
  \[ h = \frac{H}{G_o} \quad m = \frac{M}{M_o} \]

where \( K_{amp} = G_o k_d \) = normalized rate constant
\( \alpha_f = K_{amp}/\text{PEB} \) = 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)
  \[ h = 1 - e^{-C \phi h} \]
- 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.
  \[ \frac{\partial H}{\partial t} = \frac{\partial}{\partial z} \left( D_H \frac{\partial H}{\partial z} \right) \]
  (1D diffusion equation)

  where \( D_H \) = diffusivity of acid in the polymer

  \[ \frac{\partial H}{\partial t} = \nabla \left( D_H \nabla H \right) \]
  (3D diffusion equation)

PEB Diffusion
- Diffusion is a convolution of the latent image with the DPSF \([h^*(x) = \text{after-bake latent image}]:\)
  \[ h^*(x) = h(x) \otimes \text{DPSF} \]

Reaction-Diffusion
- Because of diffusion, \( h \) is not locally constant
  \[ h_{\text{eff}}(x) = \frac{1}{t_{\text{PEB}}} \int_{0}^{t_{\text{PEB}}} h(x, t = 0) \otimes \text{DPSF} \, dt \]

Deblocking responds to the time-average of the acid concentration, \( h_{\text{eff}} \)

\[ m(x) = e^{-\alpha_f h_{\text{eff}}(x)} \]
Reaction-Diffusion Point Spread Function

\[ RDPSF = \frac{1}{t_{PEB}} \int_{0}^{t_{PEB}} DPSF \, dt \]

In 1D: \[ RDPSF(x) = 2e^{-x^2/2\sigma_D^2} \frac{H}{\sigma_D} \text{erfc} \left( \frac{H}{\sqrt{2}\sigma_D} \right) \]

where \( h(x) = h(x, t = 0) \otimes RDPSF \)

\[ m(x) = e^{-\alpha x} h_0(x) \]

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

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

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

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?