






CHE323/CHE384
Chemical Processes for Micro- and Nanofabrication
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Lecture 47
Lithography:
Standing Waves and
Swing Curves

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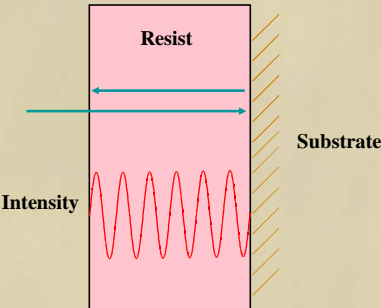
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Standing Waves

- Exposure step projects an image onto, and into, the photoresist
- If the substrate is reflective, the projected image will be reflected up through the photoresist
- Interference of incident and reflected light causes a “standing wave” of high and low intensity

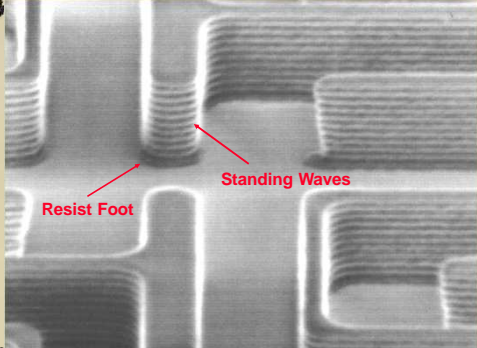
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Standing Waves

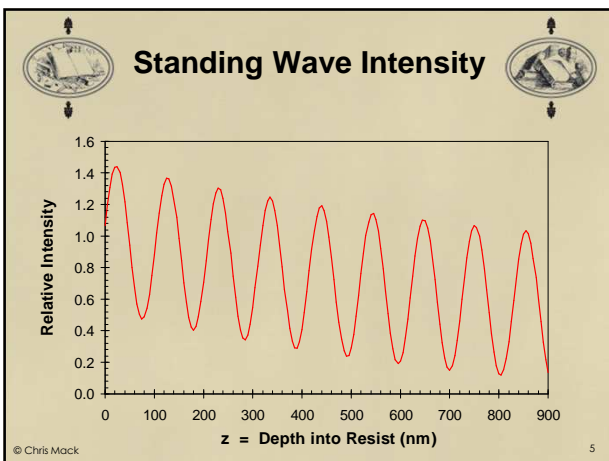


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Standing Waves



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Standing Wave Expression

Average Intensity Amplitude Period = $\lambda/2n_2$

$$I \sim e^{-\alpha z} + Re^{-\alpha(2D-z)} - (2\sqrt{R}e^{-\alpha D}) \cos(4\pi n_2(D-z)/\lambda + \phi_{23})$$

where $R = |\rho_{23}|^2$ = reflectivity of the substrate

α = resist absorption coefficient
 D = resist thickness
 n_2 = resist index of refraction (real part)
 λ = vacuum wavelength
 ϕ_{23} = phase change of substrate reflectivity

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Reducing The Standing Wave Effect

$$I \sim e^{-\alpha z} + Re^{-\alpha(2D-z)} - \left(2\sqrt{R}e^{-\alpha D}\right) \cos(4\pi n_2(D-z)/\lambda + \phi_{23})$$

- Increase resist absorption (add dye to photoresist)
- Decrease substrate reflectivity: use Bottom Antireflection Coating (BARC)
- Broadband illumination, range of angles
- Post-exposure bake (PEB)

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Post-Exposure Bake

- A post-exposure, pre-development bake is used to diffuse the exposed and unexposed photoactive compound (PAC) and smooth out the standing waves
- The time and temperature of the bake are adjusted so that the diffusion length, σ_D , is optimized:

$1/2 \text{ standing wave period} < \sigma_D \ll \text{minimum feature size}$

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Standing Waves Review

- *Standing Waves* are caused by the interference of incident and reflected light
- Standing waves can cause scalloping of the resist sidewall, reducing CD control, especially at the resist/substrate interface
- A *mathematical* description of the standing waves is very useful in understanding the phenomenon
- Standing waves can be reduced by decreased substrate reflectivity (BARC), increased absorption (dyed resist), broadband exposure (range of angles), or, after the fact, by a post-exposure bake

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Swing Curve

A periodic variation in a lithographic parameter with resist thickness

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Linewidth Change Over Topography

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Reducing The Swing Curve

- Decrease substrate reflectivity (use BARC)
- Increase resist absorption (add dye)
- Broadband illumination, range of angles
- Top anti-reflection coating (TARC)

Best Solution: Bottom Antireflection Coating (BARC)

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Reflective Notching

resist

Use BARC to fix this problem as well.

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Lecture 47: What have we Learned?

- What causes a standing wave?
- Why are photoresist standing waves bad?
- Name four ways to reduce standing waves in resist. Which way is most commonly used?
- What is a swing curve?
- What is reflective notching?

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