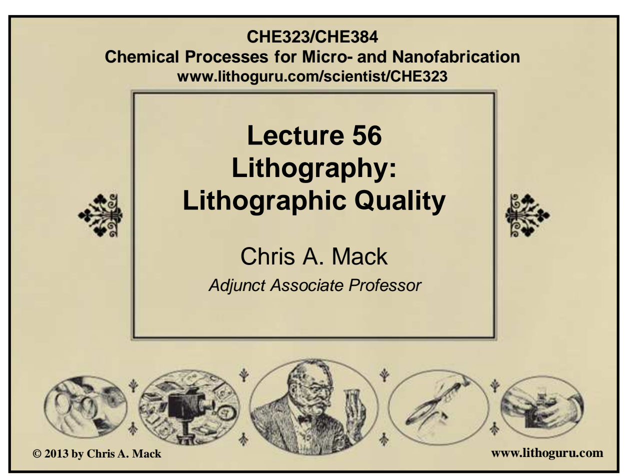
CHE323/CHE384
Chemical Processes for Micro- and Nanofabrication
www.lithoguru.com/scientist/CHE323
Lecture 56
Lithography:
Lithographic Quality
Chris A. Mack
Adjunct Associate Professor
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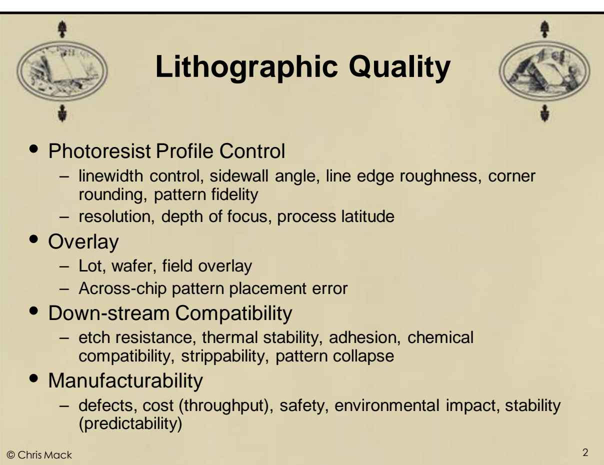
Lithographic Quality
• Photoresist Profile Control
– linewidth control, sidewall angle, line edge roughness, corner rounding, pattern fidelity
– resolution, depth of focus, process latitude
• Overlay
– Lot, wafer, field overlay
– Across-chip pattern placement error
• Down-stream Compatibility
– etch resistance, thermal stability, adhesion, chemical compatibility, strippability, pattern collapse
• Manufacturability
– defects, cost (throughput), safety, environmental impact, stability (predictability)
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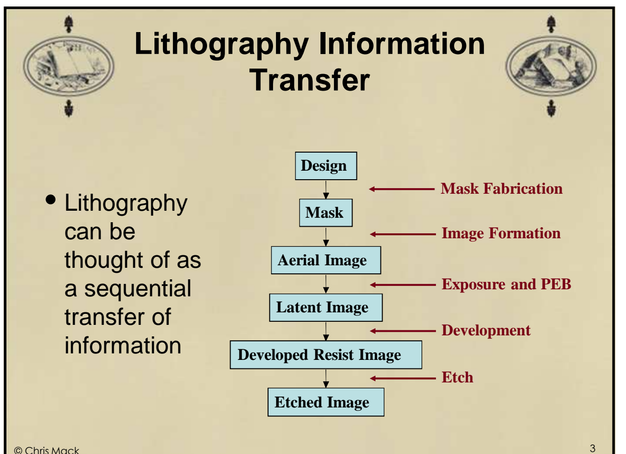
Lithography Information Transfer
• Lithography can be thought of as a sequential transfer of information
Design
Mask Fabrication
Mask
Image Formation
Aerial Image
Exposure and PEB
Latent Image
Development
Developed Resist Image
Etch
Etched Image
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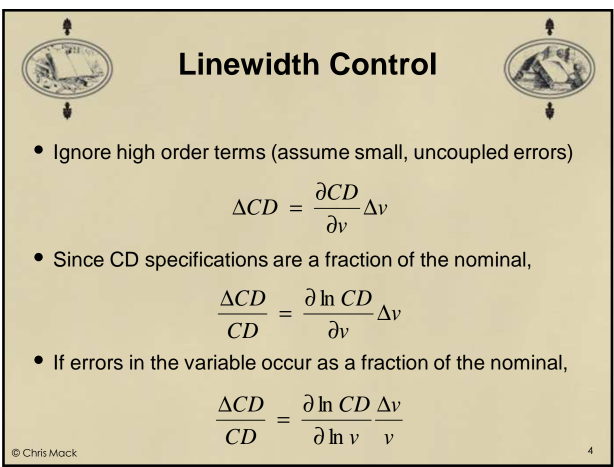
Linewidth Control
• Ignore high order terms (assume small, uncoupled errors)
$\Delta CD = \frac{\partial CD}{\partial v}\Delta v$
• Since CD specifications are a fraction of the nominal,
$\frac{\Delta CD}{CD} = \frac{\partial \ln CD}{\partial v}\Delta v$
• If errors in the variable occur as a fraction of the nominal,
$\frac{\Delta CD}{CD} = \frac{\partial \ln CD}{\partial \ln v}\frac{\Delta v}{v}$
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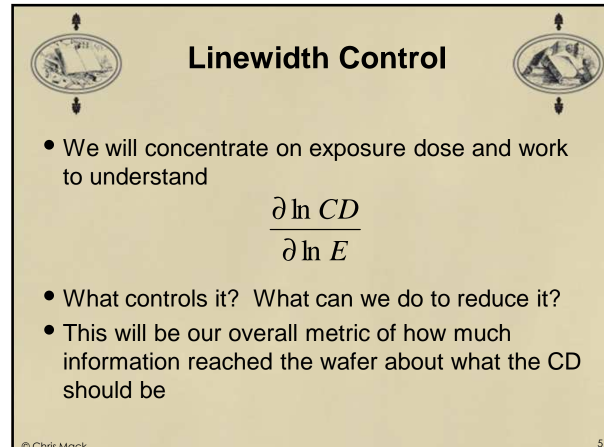
Linewidth Control
• We will concentrate on exposure dose and work to understand
$\frac{\partial \ln CD}{\partial \ln E}$
• What controls it? What can we do to reduce it?
• This will be our overall metric of how much information reached the wafer about what the CD should be
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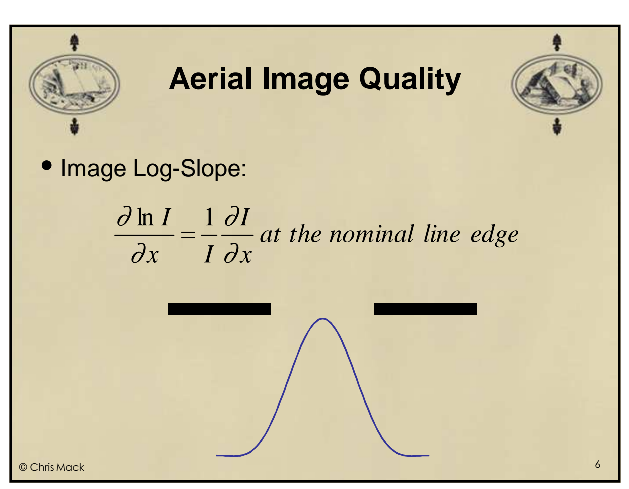
Aerial Image Quality
• Image Log-Slope:
$\frac{\partial \ln I}{\partial x} = \frac{1}{I}\frac{\partial I}{\partial x}$ at the nominal line edge
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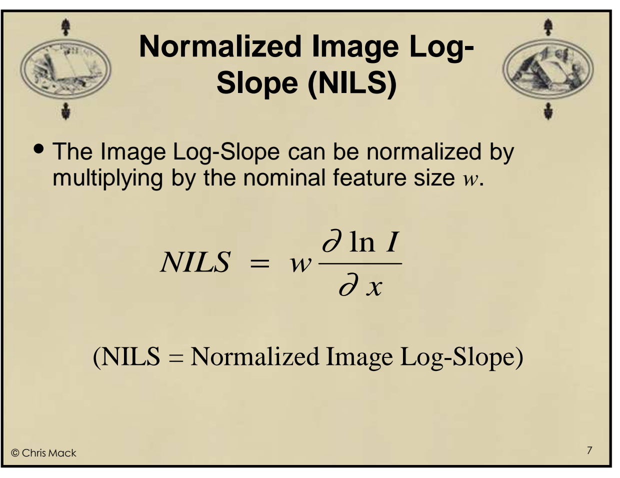
Normalized Image Log-Slope (NILS)
• The Image Log-Slope can be normalized by multiplying by the nominal feature size w.
$$NILS = w \frac{\partial \ln I}{\partial x}$$
(NILS = Normalized Image Log-Slope)
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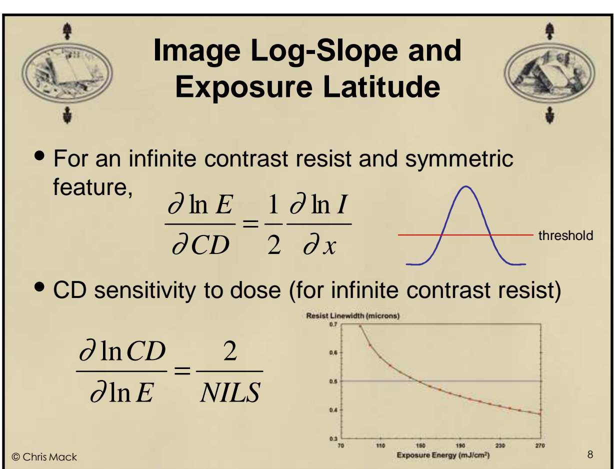
Image Log-Slope and Exposure Latitude
• For an infinite contrast resist and symmetric feature,
$$\frac{\partial \ln E}{\partial CD} = \frac{1}{2}\frac{\partial \ln I}{\partial x}$$
threshold
• CD sensitivity to dose (for infinite contrast resist)
$$\frac{\partial \ln CD}{\partial \ln E} = \frac{2}{NILS}$$
Resist Linewidth (microns)
Exposure Energy (mJ/cm²)
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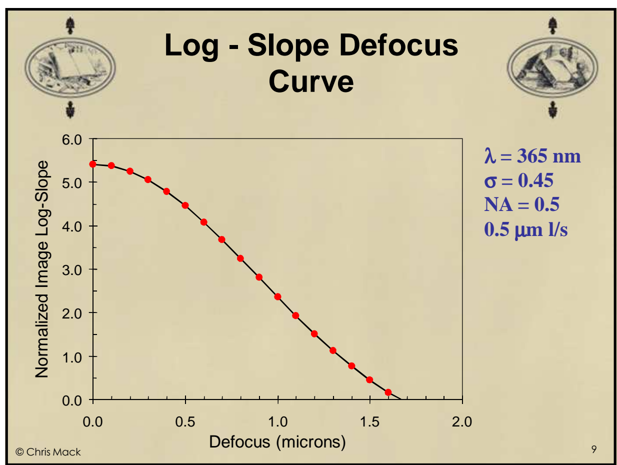
Log - Slope Defocus Curve
Normalized Image Log-Slope
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0.0
0.5
1.0
1.5
2.0
Defocus (microns)
λ = 365 nm
σ = 0.45
NA = 0.5
0.5 μm l/s
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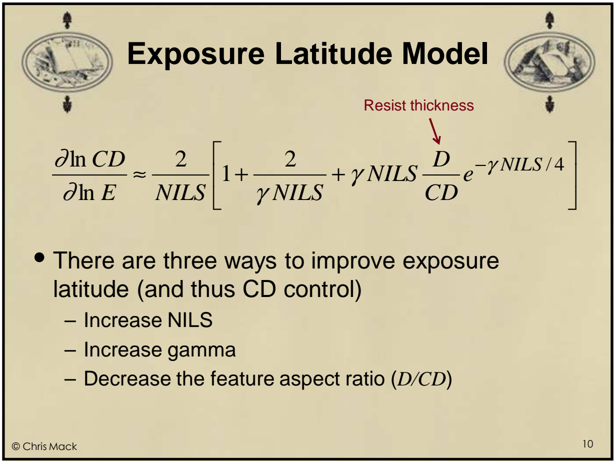
Exposure Latitude Model
Resist thickness
$$\frac{\partial \ln CD}{\partial \ln E} \approx \frac{2}{NILS}\left[1 + \frac{2}{\gamma NILS} + \gamma NILS \frac{D}{CD} e^{-\gamma NILS/4}\right]$$
• There are three ways to improve exposure latitude (and thus CD control)
– Increase NILS
– Increase gamma
– Decrease the feature aspect ratio (D/CD)
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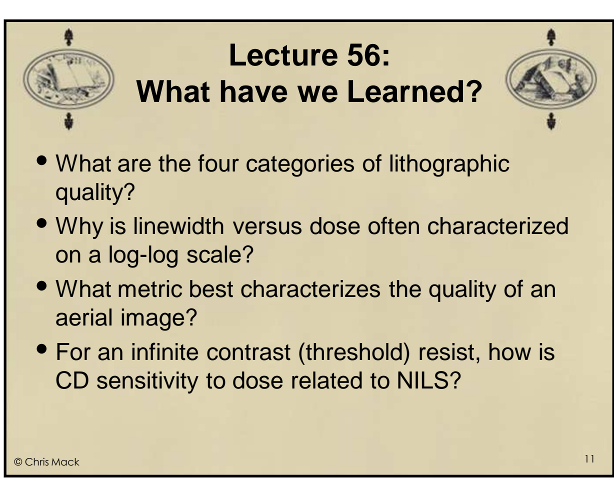
Lecture 56:
What have we Learned?
• What are the four categories of lithographic quality?
• Why is linewidth versus dose often characterized on a log-log scale?
• What metric best characterizes the quality of an aerial image?
• For an infinite contrast (threshold) resist, how is CD sensitivity to dose related to NILS?
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