EE143, Fall 2010

Homework Assignment # 2 (Due Sept 17, Friday 9am)

Reading Assignment
Jaeger, Chap 2
EE143 Lecture Notes

Problem 1 How to choose a stepper
An established optical lithography process using G-line illumination (λ =436 nm) can produce a minimum printable feature (=**k** • λ/NA) of 0.5 μm with a Depth of Focus (= $\lambda/2(NA)^2$) of 1 μm.
A new IC product requires a minimum printable feature of 0.3 μm with a Depth of Focus = 0.4 μm.
Two optical steppers are available with the following specifications:

	λ	NA
Stepper A	365 nm (I-line)	0.6
Stepper B	248 nm (excimer laser)	0.5

Assuming the technology factor **k** for minimum feature remains the same, which stepper will meet both the minimum feature and DOF requirements? Show calculations to justify your choice.

Problem 2 Thermal expansion of glass mask and Si
The linear expansion coefficient of glass mask plate is 9×10^{-6} /°C and that of Si is 2.3×10^{-6} /°C. The *maximum* allowable error due to thermal run in/out is ±0.5 μm across a 100mm diameter Si wafer.
Calculate the required ambient temperature tolerance ΔT for:
(i) Contact printing - assuming mask and wafer are at same ambient temperature.
(ii) Projection printing - the mask temperature is maintained constant but the Si wafer will follow the ambient temperature.

Problem 3 Overlay Accuracy
Overlay error is checked at the top, bottom, left and right edges, and center of a 100mm Si wafer. The observed errors in x and y (in μm) are found to be :

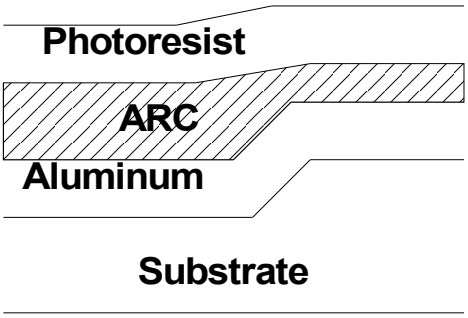
	Top	Right	Center	Left	Bottom
x	0.0	0.7	0.5	0.3	1.0
y	-0.3	0	-0.5	-1.0	-0.7

Analyse the error in/out , rotational and translational misalignment.

Problem 4 Standing wave and antireflection coating

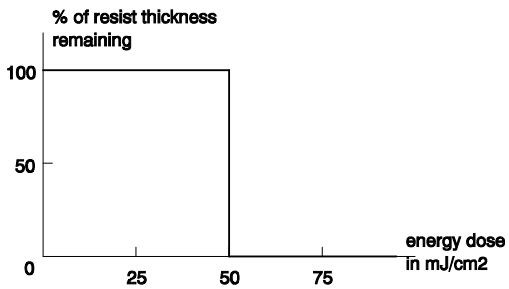
(a) Use one example to illustrate why the standing wave effect can be problematic when the developed resist is used as an etching mask.

(b) Photoresist lines often show variation of widths when they are patterned over steps with highly reflective surface. To minimize this linewidth variation, an anti-reflective coating (ARC) of polymer is spun on the substrate prior to the application of the resist. The attached figure shows the cross-section when we want to pattern an aluminum line running acrosss a substrate step. Discuss two mechanisms with which the ARC will help to minimize the linewidth variation.

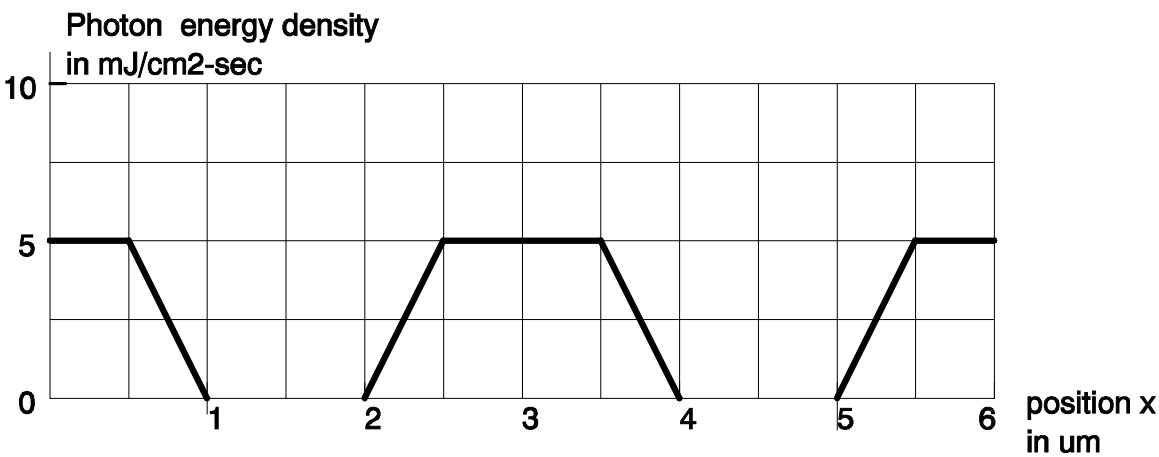


Problem 5 Resist Contrast, Energy Density, and Energy Dose

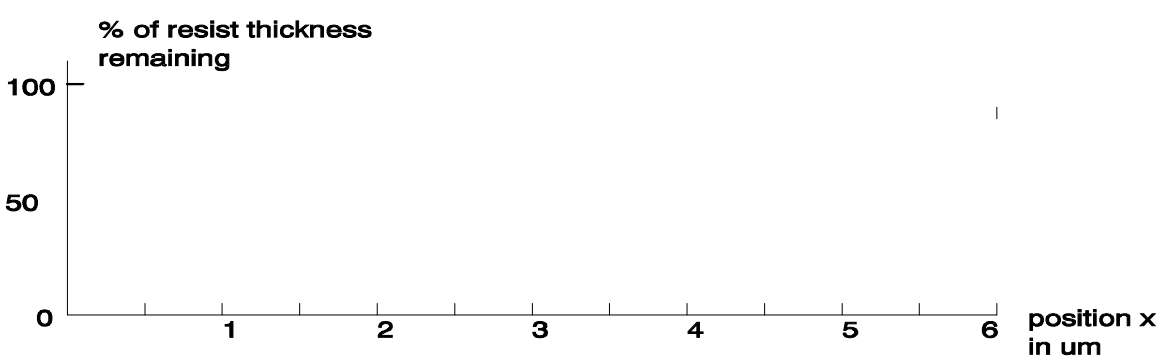
(a) A positive photoresist has the following response to photon energy dose.
What is the contrast (γ) of the resist?



(b) The lithography mask consists of parallel lines of opaque and transparent regions. After passing through a projection lens systems, the photon intensity has the following spatial variation. The intensity of the photons is expressed as mJ/ (cm^2 –sec).
The resist described in part(a) is exposed to the following intensity profile.



For simplicity, we assume the resist development proceeds only in the thickness direction and not laterally.
(i) Sketch the cross-section of the resist (solid line) after development with an exposure of 10 seconds.
(ii Sketch the cross-section of the resist (dash line) after development with an exposure of 20 seconds.



Problem 6 Qualitative questions

(a)
Fill in the table below with desired values (High, Low, or Depends) for the following optical lithography parameters and give the reasoning for your choice. No credit will be given for answers without explanations.

Parameter	Desired Value (High, Low, or Depends)	Reason
λ/NA		
Aerial Image contrast		
Slope of aerial image intensity versus position		
Resist Contrast		
Resist Sensitivity		
Resist optical absorption coefficient		

(b) Discuss the major advantages and disadvantages of E-beam lithography.