ChE 384T/323 Exam I Name______________________________

1. You have found a new transparent liquid with an index of refraction of 2.0.

   a. (5 pts) What improvement in resolution would you expect to see as a result introducing this liquid into the gap between the final lens of a microscope and the object being observed?? Show some work.

      $R = k\frac{\lambda}{\uparrow\textcircled{n}\sin\theta}$ * double the resolution

   b. (5 pts) If you introduce your liquid into the gap between the final lens of a step and repeat projection printer and the photoresist coated on a wafer, What improvement in resolution would you expect to see. Show some work.

      does nothing

2. ( 5 pts) You are designing a mask for projection lithography that must print 150 nm full-pitch, 1:1 line/space patterns onto a wafer. Ignoring all other effects, if the magnification of the lens system is 4:1, what should be the width of the chromium LINES on the mask? Show some work.

   each line and space is 75 nm

   4:1 magnification.

   $75 \times 4 = 300$ nm

3. ( 3 pts) When plane waves are diffracted through a slit, what happens to the angle of diffraction:

   a. As the slit width is decreased. wider (increase)

   b. As the frequency is decreased. wider (increase)

   c. As the wavelength is decreased. narrower (decrease)

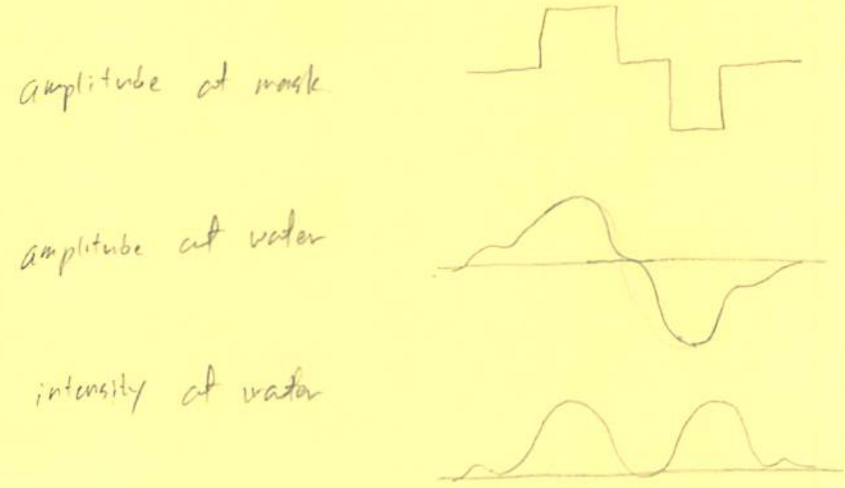
4. (15 pts) The Levenson phase mask provides a significant improvement in the aerial image of a grating mask. The drawing below shows a simple chromium on fused silica mask. Assuming that you are doing lithography at 400 nm and the index of refraction of fused silica is 2.0 (it is not!) show (sketch) how you could modify the mask in two different ways to create a Levenson phase mask. Please be precise about the dimensions of changes you would make. You do not need a calculator to work this problem.

Phase shifting

$\delta = 0.5\lambda/(n-1)$

$= 0.5 \times 400\,nm/(2-1)$

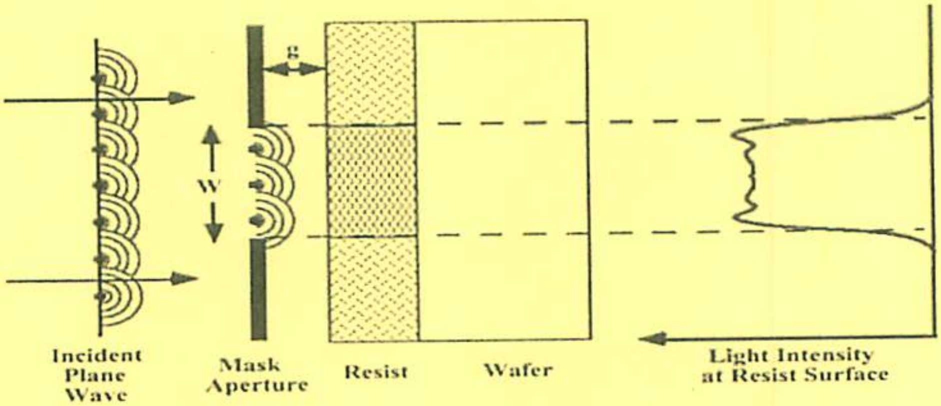
$= \underline{200\,nm}$ depth



therefore,

plus,

5. (15 pts) The diagram below was used to discuss Huygens' Theory, which treats the propagation of light `through a small slit as if there were an infinite number of point sources of spherical wavelets. Based on application of this theory, there is a relationship between the minimum feature size that can be printed, W, the wavelength of the imaging radiation and the gap between the mask and the resist. What is the smallest feature that can be printed by a proximity aligner if the wave length is 200 nm and the gap is 800 nm? You do not need a calculator to work this problem. Please show your work.



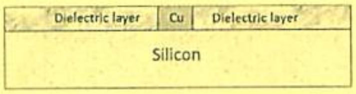
$W \sim \sqrt{\lambda \cdot g}$

$W = \sqrt{200 \cdot 800}$ nm

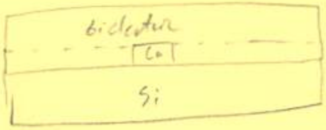
$= \sqrt{160000}$ nm

$= 400$ nm //

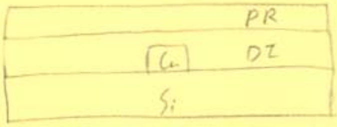
6. (15 Pts) (Given a wafer with a copper conductor line imbedded in a dielectric layer as depicted below, show the unit process steps required to generate a via imbedded in dielectric that offers connection to this wiring layer using the damascene process.



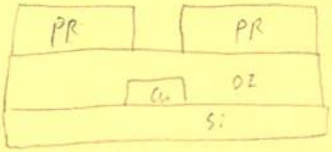
Deposit dielectric



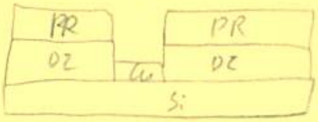
Deposit photoresist



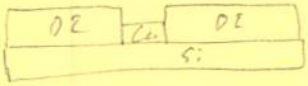
Lithography



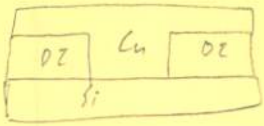
etch dielectric



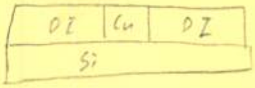
Strip Photoresist



electroplate Copper



CMP
(chemical-mechanical planarization)



7. (4 pts) Please explain why it is much more difficult and expensive to inspect EUV masks than it is to inspect masks for 193nm lithography.

* alterating multi-layer stack serves as a mirror or reflector which make it hard to be inspected with conventional optical tools

* hard to achieve EUV wavelength

8. (5 pts) Explain the Gaussian beam and variable shape writing strategies for electron beam exposure tools then list two advantages and two disadvantages of Gaussian beam lithography over the variable shape approach.

Gaussian beam : Great for unit process development and device prototyping.

Variable shaped beam : Needed for full field pattern generation and for image placement
this system is e-beam tool of choice for writing 4x photomasks,
and is the correct choice if you need to write fast.
but it doesn't have great resolution.

G : slower, prints single pixels w/ beam size < 10 nm, higher resolution

V : faster, prints shapes that depend on size of aperture, lower resolution

9. (3 pts) List three advantages of projection printing over proximity printing.

a. prevent the mask from introducing defect
b. more uniform image
c. no need to replace mask

10. (5 pts) What caused the demise of the x-ray proximity printing program?

· mask: issues.

11. (10 pts) Explain the term polyphotolysis and why this is such an important part of photoresist design.

$I \rightarrow S$

$I-I \rightarrow S-I \rightarrow S-S$

$I-I-I \rightarrow S-I-I \rightarrow S-S-I \rightarrow S-S-S$

the decomposition or separation of small molecules in a polymer chain by the action of light

This contributes to a threshold like dissolution rate response to exposure.
(solubility switching) - non-linear dissolution rate

12. (10 pts) Please respond with T for true or F for false of X for no response. Your score will be computed as number of correct responses minus the number of incorrect responses or 0, whichever is greater. In other words, guessing is not a great idea.

1. F SADP stands for Sidewall Angle Double Patterning
2. T At 10 KeV, e-beam lithography has fewer proximity correction issues than at 25KeV
3. F The famous KTFR resist was comprised of gelatin and a difunctional aryl azide.
4. T Both the photopolymer resist and KTFR depended on cross-linking as the mechanism for modulation of solubility.
5. T The SCALPEL e-beam exposure machine failed because of electron-electron repulsion in the beam cross over point.
6. T There is a pellicle material available for use with EUV lithography.
7. F The throughput of imprint lithography is currently limited by light source brightness
8. T The first archival photograph is on display at the University of Texas
9. T The MAPPER system has more than 1000 individual electron beams.
10. F Chromium is used to generate image contrast on traditional optical Masks and on EUV masks.