ChE 384T / 323

Fall 2018
Dr. Willson

First Midterm Exam

You will take two tests this morning, one in engineering and one in integrity. I want you to get A's on both of these tests but if you are to fail one of the tests, let it be the one on engineering.
GW

Name (Print as it appears on the Class Roster) Key.

Signature

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Name_____

1a.(10)_____ ( )

1b.(10)_____ ( )

2. (10)_____ ( )

3. (6)_____ ( )

4. (15)_____ ( )

5. (4)_____ ( )

6. (10)_____ ( )

7. (6)_____ ( )

8 (2)_____ ( )

9. (6)_____ ( )

10.(6)_____ ( )

11.(15)_____ ( )

Total _____

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1. You have found a new liquid that has high surface tension and is transparent at all wavelengths from 600 to 157nm and it has a wavelength independent index of refraction of 2.0. This means that you could potentially have a high impact on science and engineering.

   a. (10 pts) What percentage of improvement in resolution would you expect to see as a result of introducing this new liquid into the gap between the final lens of a microscope and the object being observed?? Show some work.

$$R_1 = \frac{k\lambda}{n_1 \sin\theta} \qquad R_2 = \frac{k\lambda}{n_2 \sin\theta}$$

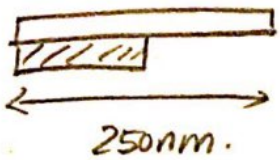
$$\frac{R_2 - R_1}{R_1} \times 100\%$$

$$\frac{\frac{1}{2} - \frac{1}{1}}{\frac{1}{1}} \times 100 = 50\% \text{ improvement}$$

   b. (10 pts) What percentage of improvement in resolution would you expect to see 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. Assume that you made no other changes? Show some work.

No % improvement

2. (10 pts) You are designing a mask for projection lithography that must print 250 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.



$$\frac{250nm}{2} \times 4 = 500nm.$$

3. (6 pts) When plane waves are diffracted through a slit, what happens to the angle of diffraction:

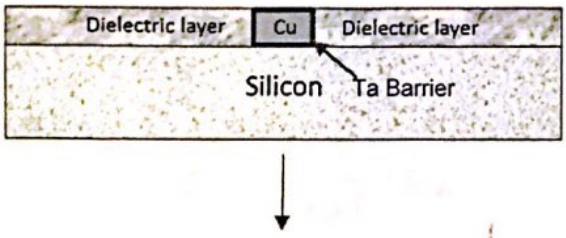
   a. As the slit width is decreased. Increase

   b. As the frequency is decreased. Increase

↑.

c. As the wavelength is decreased. Decrease

4. (15 Pts) Given a wafer with a copper conductor line clad in a tantalum diffusion barrier that is imbedded in a dielectric layer as depicted below, show (sketch) the unit process steps required to generate a via imbedded in dielectric that offers connection of this copper wiring layer to the next copper layer. You should depict the damascene process.



Lecture 13 Slide 19

5. (4 pts) You want to observe features on a bacterium that are 1 micrometer in diameter. If you need 500nm, visible light to see the image directly and you assume that the Rayleigh constant is 0.5, what is the minimum numerical aperture of a lens that would allow you to see this feature? You do not need a calculator to work this problem.

$$R = \frac{k\lambda}{NA}$$

$$\frac{1000nm}{} = \frac{0.5 \times 500\,nm}{NA} \Rightarrow NA = 0.25$$

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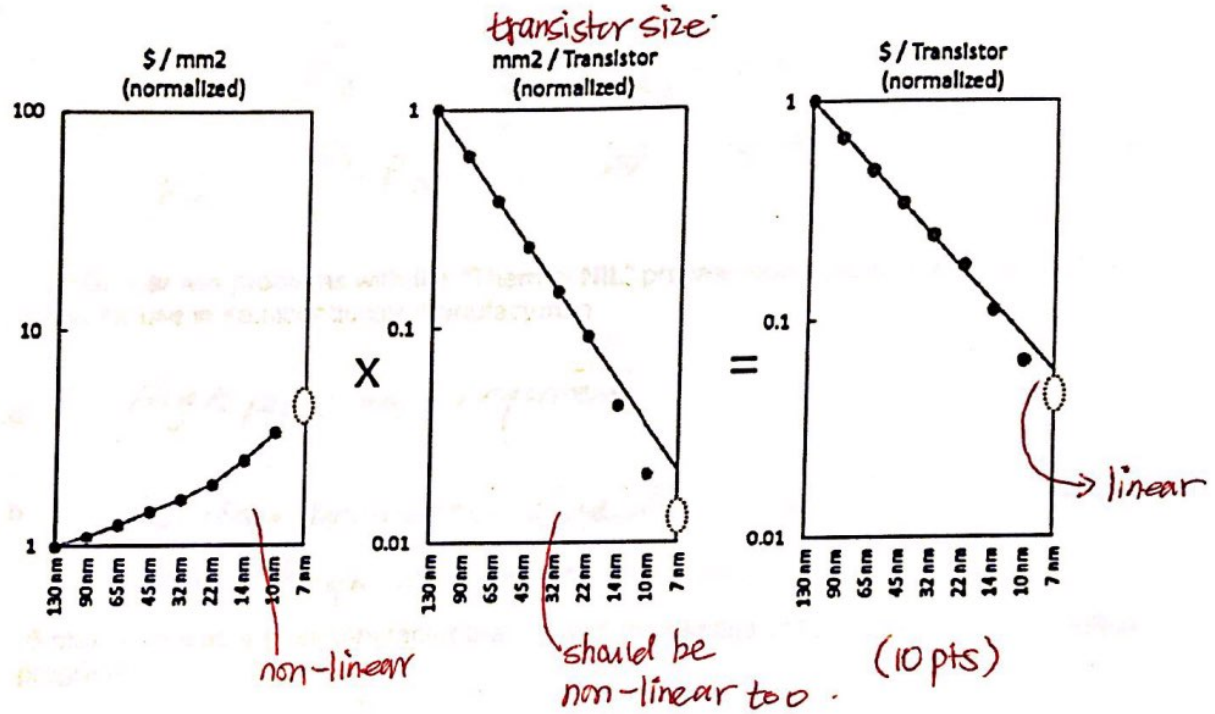
6. (10 Pts). The plots below were on the cover slide for lecture 7 and were discussed at some length because they define an important issue for the semiconductor industry. Please explain what this series of plots teaches relative to Moore's Law and the future of nanofabrication. Limit your answer to 3 very legible sentences.



(10 pts)

Moore's law explanation (w/o explanation of non-linearity) (6pts)

other explanation about semiconductor industry (6pts)
or read graph

7. (6 pts) Assuming a constant numerical aperture and constant Rayleigh factor, what percent of increase in resolution that would have been realized had the industry managed to change from 193nm to 157nm lithography?

$R \propto \lambda$

$\frac{R_1}{R_2} = \frac{\lambda_1}{\lambda_2}$

$R_1 = \frac{193}{157} R_2$

$\rightarrow R_2 = \frac{157}{193} R_1$

$R_2 = 0.813 R_1$

$\Rightarrow$ 18.7% improvement in resolution

8. (2 pts) List two problems with the "Thermal NIL" process that was proposed by Professor Chou for use in semiconductor manufacturing.

a. High pressure required

b. Overlay problem due to image distortion under high temperature and pressure

9. (6 pts) What was the primary factor that caused the demise of the x-ray proximity printing program?

MASK & Alignment

10. (6 pts) List three advantages of projection printing over proximity printing.

a. - Reduce $\Rightarrow$ yield

b. - MASK reduction factor

c. - ~~contact~~ gap influence on resolution

11. (15 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/gambling is not a great idea.**

a) T CMP stands for chemical mechanical polishing.

b) T E-beam lithography at 25KeV has higher resolution that that at 10KeV

c) F The famous KTFR resist was comprised of gelatin and a difunctional aryl azide.

d) T Both the photopolymer resist and KTFR depended on cross-linking as the mechanism for modulation of solubility.

e) F SADP is an acronym for Sidewall Aligned Double Patterning

f) T There is now a pellicle material available for use with EUV lithography.

g) F The throughput of imprint lithography is currently limited by light source brightness

h) T The first archival photograph is on display at the University of Texas

i) T The absolute minimum for the Rayleigh "Constant" is 0.25.

j) F Fused silica ("quartz glass") is used to manufacture lenses for 248nm, 193nm and 157nm lenses.

k) F The first computer chips manufactured by EUV lithography went on the market in 2018.

l) T Calcium Fluoride is birefringent

m) T Mirror based lens systems do not suffer from chromatic aberration.

n) T Catadioptic lenses have mirrors.

o) F Electron beam lithography is of no importance to the semiconductor industry because the throughput is just too slow.

mask.