ECE 6450 Introduction to Microelectronics Technology

Exam 2

November 10, 2014

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Solutions

Print your name clearly:

Instructions:
Read all the problems carefully and thoroughly before you begin working. You are allowed to use 1 new sheet of notes (2 pages front and back), your sheet from previous exams as well as a calculator. There are 100 total points in this exam. Observe the point value of each problem and allocate your time accordingly. SHOW ALL WORK AND CIRCLE YOUR FINAL ANSWER WITH THE PROPER UNITS INDICATED. Write legibly. If I can not read it, it will be considered to be a wrong answer. Do all work on the paper provided. Turn in all scratch paper, even if it did not lead to an answer. Report any and all ethics violations to the instructor. Good luck!

Sign your name on **ONE** of the two following cases:

I did not observe any ethical violations during this exam:

I observed an ethical violation during this exam:

Problem 1. (17 points total):
True/False and Multiple Choice (**circle** the answer or answers that are correct):

a.) (3 points) Gas A has a vapor pressure 10 times that of gas B. Both gases are to be leaked into a vacuum chamber with negligible pressure through a small orfice (tube of negligible length). When in the molecular flow regime, what relationship should the orfice area A have to Orfice area B such that the mass flow throughput of each gas is identical?

1.) (Area A) = 10 (Area B)
2.) (Area A) = 0.1 (Area B)
3.) (Area A) = (Area B)
4.) Area A should be the cousin of Area B so that they can legally marry in Georgia

(1 points each)

b.) At high temperatures, radiant power loss must be less than the absorbed power in order to maintain a constant temperature. $\geq$
True or False (circle the correct answer)

c.) A rapid thermal diffusion is often used to provide high degrees of heat to repair implant damage but short periods of time so as to not diffuse dopants very far.
True or False (circle the correct answer)

e.) Damascene processing typically uses a seed layer and/or diffusion barrier to prevent the copper from diffusing into sensitive devices.
True or False (circle the correct answer)

f.) A lift off process always uses two photoresist layers to form a discontinuity in which the lifted off material can be easily sheared. or re-entrant profile
True or False (circle the correct answer)

g.) An added external DC bias is always needed for plasmas to drive ions toward the surface for reaction. Induced DC
True or False (circle the correct answer)

h.) In the viscous flow regime, the conductance of a tube decreases with decreasing pressure making the simple exponential pump down time expression a gross underestimate.
True or False (circle the correct answer)

i.) In a plasma or CVD deposition process, uniform step coverage (no thin spots or breaks) can be enhanced by increasing pressure.
True or False (circle the correct answer)

j.) Etch rate in a plasma etch can be increased by increasing the DC bias between the glow discharge region and the wafer increasing the mechanical component of the etch.
True or False (circle the correct answer)

k.) UV light is never used for RTP processing to enhance chemical reactivity.
True or False (circle the correct answer)

l.) Cryopumps operate by physically pushing gas molecules with rapidly spinning blades.

True or False (circle the correct answer) Turbopump

m.) As the pressure in an evaporator increases, the virtual source moves from the "real source" towards the wafers.

True or False (circle the correct answer)

n.) Wet etches are rarely used in semiconductor processing because they are expensive compared to plasma etches.

True or False (circle the correct answer)

o.) For a projection system to be able to expose a resist properly, the projector's MTF should be greater than the CMTF of the resist.

True or False (circle the correct answer)

p.) Whew, I am sure glad I made it through all those true/false questions!

True or False (circle the correct answer)

Problem 2. (25 points total in 4 parts):

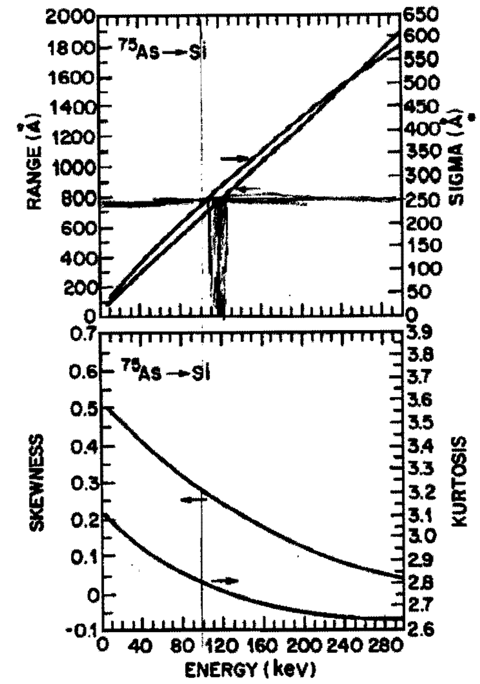


FIGURE 7 (CONTINUED)

As an engineer for Intel, you are asked to develop an arsenic (As) implant into Si such that the Si crystal is converted to amorphous material at a depth from the surface of 750 angstroms. The implanter your company uses has a large total beam current of 10 mA in a 200 mm diameter aperture and a source to wafer spacing of 3 meters. Afterwards, the material is found to contain a maximum concentration of 1.596e20 cm^{-3} arsenic (As).

What is (a- 5 points) the **implant voltage (not energy)**, (b-10 points) the **critical dose** for the Si, and (c-5 points) the **implant time** needed for a 200 mm diameter (area = 314.16 cm^2) wafer? (d- 5 points) **Is the implant skewed toward or away from the surface**?

Clearly indicate and circle your values used from the charts.

@ 750 Å range

(Sigma) $\sigma \simeq 250$ Å

Skewness $\simeq +0.3$

Energy $\simeq$ 120 keV

a) **Voltage = 120 kV**

b) $n(x) = \frac{Q_T}{\sigma\sqrt{2\pi}} e^{-(x-R_p)^2/2\sigma_p^2}$

$1.596e20\ cm^{-3} = \frac{Q_T}{\sigma\sqrt{2\pi}}(1) \Rightarrow$ **$Q_T = 1e15\ cm^{-2}$**

$\sigma \rightarrow$ 250e-8 cm

c) $Q_T = \frac{1}{q\,Area}\int I\,dt$

$t = 10^{15}(1.6e-19)(314.16)/10mA$ (q, Area)

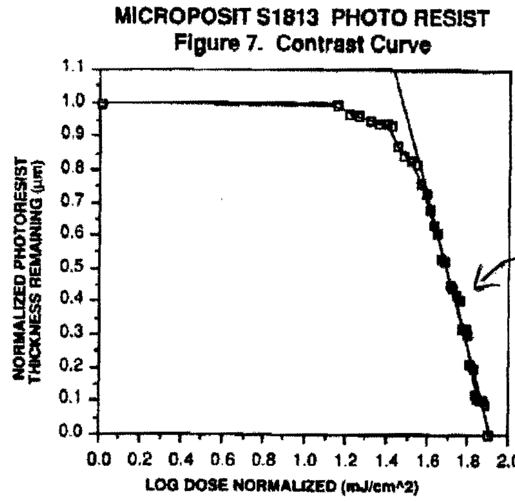
t = 5.0 seconds

d) **Positive skewness ⟹ leaning away from the top surface**

Problem 3. (53 points total):

A common photoresist, Shipley Microposit S1813, has a contrast curve as shown in the figure to the right (taken from actual datasheets).

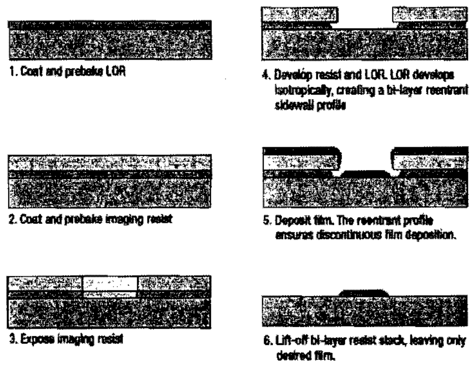
It is desired to use this S1813 resist as the top coat resist along with a new bottom coat resist you are to invent. The goal is to have a resist bilayer stack that will aid in the lift off process as shown below.



MICROPOSIT S1800 SERIES PHOTO RESISTS

Table 1. Dill Parameters

	365 nm		436 nm	
Photoresist	A (μm^{-1})	B (μm^{-1})	A (μm^{-1})	B (μm^{-1})
S1813	1.07	0.31	0.61	0.08



Process flow above taken from LOR Photoresist datasheet.

When used alone, it is found that the thickness of the S1813 resist remaining after exposure and development has a slope (as indicated by the linear regression fit line in the figure) of,

$$\text{Thickness Remaining} = 4.3416 - 2.2681\ \text{Log}_{10}(Dose)$$

a) (5 Points) What is the 365nm light absorption coefficient of the fully exposed S1813 resist?
b) (5 Points) Find S1813 resist's D_0
c) (5 Points) Find S1813 resist's D_{100}
d) (5 Points) Find the S1813 resist's contrast

$\alpha_{unexposed} = B + A$

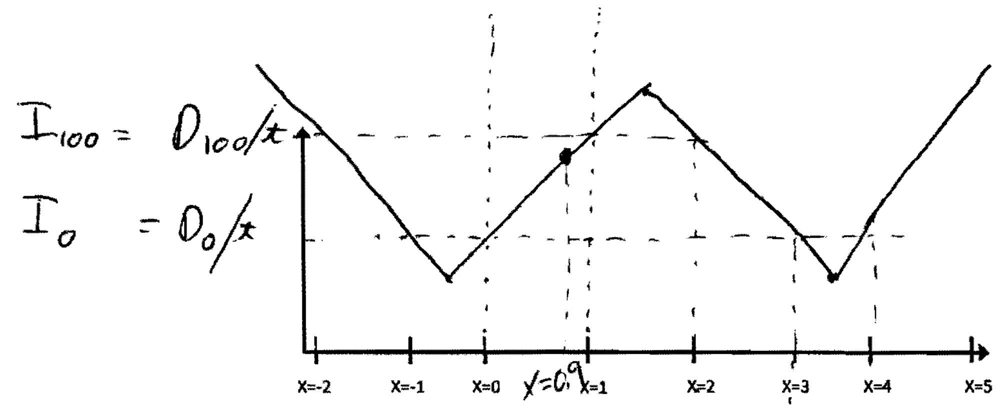
a) $\alpha_{exposed} = B = 0.31\ 1/\mu m$

Same as previous exam

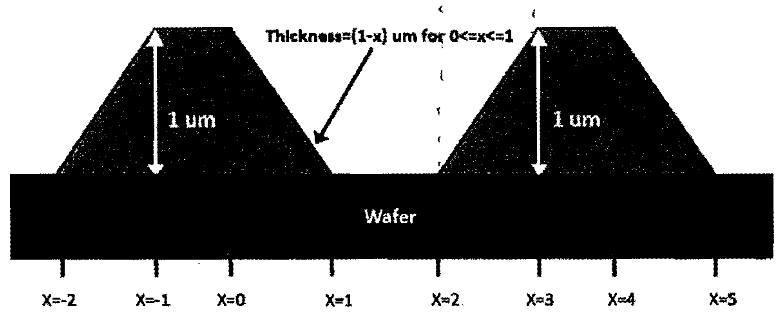
b) $D_0 = 10^{((1-4.3416)/-2.2681)} = 29.73\ mJ/cm^2$

c) $D_1 = 10^{(4.3416/2.2681)} = 82.07\ mJ/cm^2$

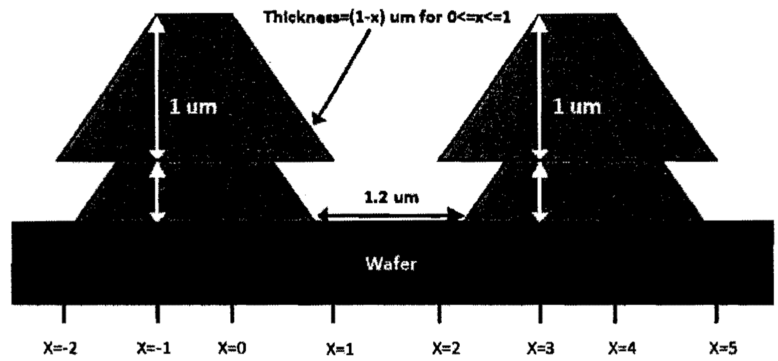
d) $\gamma \equiv \text{contrast} = \frac{1}{\log\left(\frac{D_{100}}{D_0}\right)} = 2.26$



Part e) →



Parts f and g) →



similar but easier than previous exam

e) (5 Points) It is found that when S1813 resist is 1 μm thick and the areal image is a triangular repetitive saw tooth pattern (something simple for calculation sake), a developed photoresist pattern shown in the above figure is obtained. On the above graph, sketch and label the light intensity pattern of the areal image for a 10 second exposure. Be sure to label points x=0 and x=1 um.

$I_{100} = 8.207\ mW/cm^2$

$I_0 = 2.973\ mW/cm^2$

f) (15 Points) Using the absorption coefficient of the unexposed S1813 resist (i.e. make an assumption the absorption coefficient remains unchanged during exposure), what new resist contrast is required for a bottom layer resist such that the resist opening at the wafer/resist interface is at least 1.2 um wide?

g) (13 Points) What constraint on the thickness exists to ensure the bottom layer opening is at least 1.2 um wide?

You may show your work here

f) find new required D_{100}:
Dose equation of straight line:

$$D(x) = 29.73 + (82.07 - 29.73)X$$

$$D(x = 0.9\ \mu m) = 76.836\ mJ/cm^2$$

Since α is unchanged from the 1st resist,

D_o must also be the same,

$$\therefore\ \gamma_{new} = \frac{1}{\log_{10}\left(\frac{76.836}{29.73}\right)} = \boxed{2.425}$$

g) $\alpha_{unexposed} = A + B = 1.38\ \mu m^{-1}$

$$\gamma = 2.26 = \frac{1}{\beta + \alpha T_R}$$ ($T_R \rightarrow 1\ \mu m$)

$$\beta = -0.9375$$

$$2.425 \geq \frac{1}{1.38T - 0.9375}$$

$$T \leq 0.978\ \mu m$$