ECE 6450 Introduction to Microelectronics Technology

Exam 2

October 14, 2004

Dr. W. Alan Doolittle

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

a.) (3 points) The most damage in an Ion Implantation process ...
1.) ... results from nuclear collisions
2.) ... is more dominant at high implant energy
3.) ... occurs at the surface
4.) ... occurs near the projected range

b.) (3 points) If you have a 10 liter/sec pump connected to a tube with a conductance of 10 liter/second, the effective pumping speed is ...
1.) ... 20 liters/sec.
2.) ... 10 liters/sec.
3.) ... 5 liters/sec.
4.) ... none of the above.

(1 points each)

c.) Radiant Power loss dominates over conduction and convection at high temperatures
True or False (circle the correct answer)

d.) A rapid thermal diffusion can result in more rapid diffusion than a furnace at the same temperature due to a reduces activation energy for diffusion.
True or False (circle the correct answer)

e.) Damascene processing involves polishing oxides and metals to achieve a "globally planar" surface necessary for high resolution lithography.
True or False (circle the correct answer)

f.) Solvents act as "thinners" to make the photoresist a liquid.
True or False (circle the correct answer)

g.) Plasmas possess a negatively charged central region called a glow discharge region.
True or False (circle the correct answer)

h.) The conductance of a tube decreases with decreasing pressure.
True or False (circle the correct answer)

i.) Anisotropy can be enhanced by increasing pressure.
True or False (circle the correct answer)

j.) Anisotropy can be increased by increasing the DC bias between the glow discharge region and the wafer.
True or False (circle the correct answer)

k.) Thermal equilibrium always hold true for an RTP process.
True or False (circle the correct answer)

l.) For a wafer in an RTP system, a yellow glow (λ ~590 nm) from a wafer indicates a hotter temperature than a red glow (λ~620 nm) from the same type of wafer.

True or False (circle the correct answer)

m.) Ion pumps are very good rough vacuum pumps.

True or False (circle the correct answer)

n.) An Reactive Ion Etching system is a plasma etching system operated at lower pressure and higher bias to achieve high anisotropy.

True or False (circle the correct answer)

o.) A long mean free path results from a high pressure and is very useful to achieve undercut features with a large etch bias.

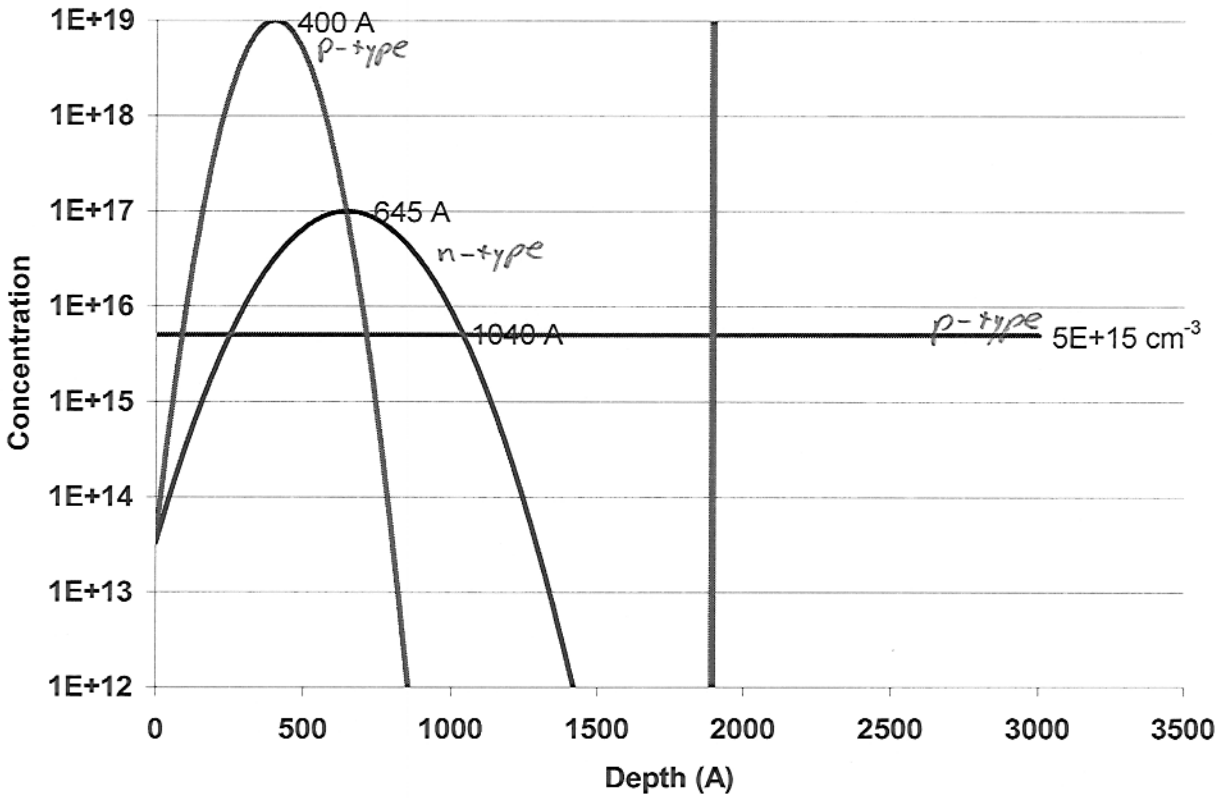
True or False (circle the correct answer)

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

True or False (circle the correct answer)

either as a gift

Problem 2. (30 points total):



As an engineer for National Semiconductor, you are asked to develop a pnp Bipolar Junction Transistor (BJT) profile as shown above. The p-type bulk wafer concentration is 5×10^{15} cm^{-3}. The implanter your company uses has a beam current of 2 μA. The n-type base implant is performed first so the peak concentration is 1e19 cm^{-3} and 400 angstroms (A) as noted in the figure. The emitter implant is then performed so the peak concentration is 1e17 cm^{-3} and 645 angstroms (A) as noted in the figure. Given the following relationships for the projected range and straggle, what implant energy and implant time must you use for a 200 mm diameter wafer for each implant?

---

n-type dopant: $R_p = 1\left(\frac{A}{KeV}\right)(E) = 645\,\mathring{A}$ $\Rightarrow E = 215$ keV $\Delta R_p = \sigma_p = 0.75\left(\frac{A}{KeV}\right)(E) = 161.25\,\mathring{A}$

---

p-type dopant: $R_p = 5\left(\frac{A}{KeV}\right)(E) = 400\,\mathring{A}$ $\Rightarrow E = 80$ keV $\Delta R_p = \sigma_p = 1\left(\frac{A}{KeV}\right)(E) = 80\,\mathring{A}$

---

where E is the implant energy in KeV.

$$Dose = Q_T = \frac{1}{q\,Area}\int_0^t I\,dt = \frac{It}{q\,Area}$$

$Area = (\pi(10cm)^2) \rightarrow 314\ cm^2$

$$= n_0\,(\sigma_p)\sqrt{2\pi}$$

You may show your work here

p-type emitter

$Q_T = (1e19)(80e{-8}\,cm)\sqrt{2\pi}$

$= 2.01e13\ cm^{-2}$

$t = \frac{(2.01e13\,cm^{-2})(1.6e{-9})(314\,cm^2)}{2e{-6}\,A}$

$t_p =$ 504 seconds ← expensive
@ 2 μA
@ 80 keV

n-type base

$Q_T = (1e17)(161.25 \times 10^{-8}\,cm)\sqrt{2\pi}$

$= 4.04e11\ cm^{-2}$

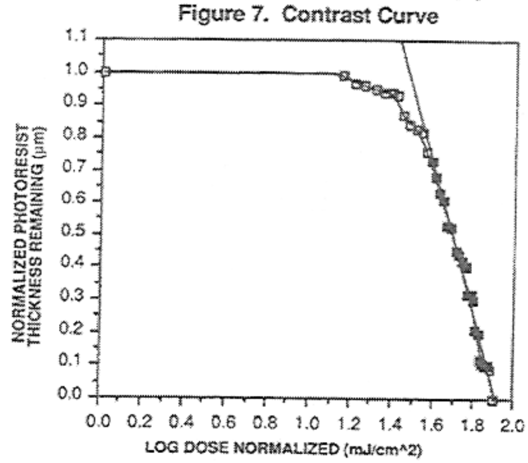
$t = \frac{(4.04e11)(1.6e{-9})(314\,cm^2)}{2e{-6}}$

$t_n =$ 10.2 seconds
@ 2 μA
@ 215 keV

Problem 3. (50 points total):

A common positive photoresist, Shipley Microposit S1813, has a contrast curve as shown in the figure to the right (taken from actual datasheets). It is found that the thickness of the resist remaining after exposure and development has a slope (as indicated by the linear regression fit line in the figure) of,

MICROPOSIT S1813 PHOTO RESIST
Figure 7. Contrast Curve



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

a) (10 Points) Find D_0
b) (10 Points) Find D_{100}
c) (15 Points) It is found that for a 1 µm thick resist, a pattern is not able to be transferred using an exposure tool with a MTF of 0.4. Explain why ***(in 1 sentence)*** and support your answer with numerical calculations.
d) (15 Points) If the resist from part (c) has an absorption coefficient, $\alpha = 1.07\ \mu m^{-1}$ what new thickness of resist is required to transfer an image using the exposure tool with a MTF of 0.4?

at D_{100}, normalized thickness = 0

at D_0, the normalized thickness = 1 (not etched)

From (*)

b) $D_{100} = 10^{(4.3416/2.2681)} = \boxed{82.07\ mJ/cm^2}$

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

c) $\text{Contrast} = \dfrac{1}{\log_{10}(D_{100}/D_0)} = 2.26$

$$CMTF = \left(\frac{10^{1/2.26} - 1}{10^{1/2.26} + 1}\right) = 0.468$$

Since, MTF = 0.4 < CMTF = 0.468, no pattern can be transfered.

d) see next page

You may show your work here

d)

$$\gamma = 2.26 = \frac{1}{\beta + \alpha T_R}$$

$$= \frac{1}{\beta + (1.07\ \mu m^{-1})(1\ \mu m)}$$

$$\frac{1}{2.26} = \beta + 1.07$$

$$\beta = -0.627$$

For a pattern to transfer, we need:

$$CMTF < MTF$$

$$\frac{10^{1/\gamma} - 1}{10^{1/\gamma} + 1} < 0.4$$

$$10^{1/\gamma} - 1 < 0.4 + (0.4)10^{1/\gamma}$$

$$(0.6)10^{1/\gamma} < 1.4$$

$$1/\gamma < 0.3679$$

$$\gamma > 2.717$$

$$\gamma = 2.717 < \frac{1}{\beta + \alpha T_R} = \frac{1}{(1.07)T_R - 0.627}$$

$$T_R < \left[\frac{1}{2.717} + 0.627\right]\frac{1}{1.07}$$

$$\boxed{T_R < 0.93\ \mu m}$$