ECE 6450 Introduction to Microelectronics Technology

Exam 2

October 9, 2008

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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. True/False: (26 points total, 2 points each):

a.) Ion Implantation processes produce most of the damage at the wafer surface where the implant energy is the highest.

True or [✓ False] (circle the correct answer)

b.) The microscopic physics of rapid thermal diffusion works identical to a furnace diffusion except the times are shorter.

True or [✓ False] (circle the correct answer)

c.) 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)

d.) Resins in the photoresist react with light to either weaken or strengthen the polymer.

True or [✓ False] (circle the correct answer)

e.) In a Negative photoresist light weakens the polymer to enhance the dissolution (act of dissolving) of the photoresist when it is placed in the developer.

True or [✓ False] (circle the correct answer)

f.) Implant dose is not well known making it less predictable than a standard diffusion.

True or [✓ False] (circle the correct answer)

g.) Channeling can result in positive skewness.

[✓ True] or False (circle the correct answer)

h.) Implanting directly inline with a major crystalline axis results in less channeling.

True or [✓ False] (circle the correct answer)

i.) Rapid Thermal Oxidation is a great way to make thin oxides since the thickness can be very accurately controlled.

[✓ True] or False (circle the correct answer)

j.) One would never want to include nitrogen (N_2O or NO gases for example) in an oxide process since this makes the dielectric more leaky.

True or [✓ False] (circle the correct answer) →Flash Memory

k.) Nitrogen is broken off the DN molecule during exposure of a positive resist.

[✓ True] or False (circle the correct answer)

l.) The acidic nature of the post-exposure photoresist makes it easier to dissolve in a base (pH>7) developer solution.

[✓ True] or False (circle the correct answer)

m.) If one wants to use ion implantation for a very shallow implant, one can use a mask on the surface but "knock on" contamination of the wafer could result.

[✓ True] or False (circle the correct answer)

Problem 2. (14 points total):

Assume all power from an RTP system is absorbed in a 4 inch diameter SiC wafer having an emissivity of 0.8 . What is the power needed to be delivered to the wafer to maintain the wafer temperature at a constant 1000 degrees C. You may neglect any edge emission and treat the wafer as having only 2 sides (i.e. treat the wafer as a 2 dimensional, 2D, object not 3D).

$$W/cm^2 = \varepsilon \sigma T^4$$

$$\text{Area} = 2\left(\cancel{D}2'' \times 2.54\ cm/inch\right)^2 \pi$$

$$\text{Area} = \cancel{91.2}\ cm^2$$

$$162.1\ cm^2$$

$$\text{Power} = 0.8\ (2 \times \text{Area})\ 5.6697 \times 10^{-8} \left(\frac{W}{m^2K^4}\right)\left(1e4\frac{m^2}{cm^2}\right)\left(1273\right.$$

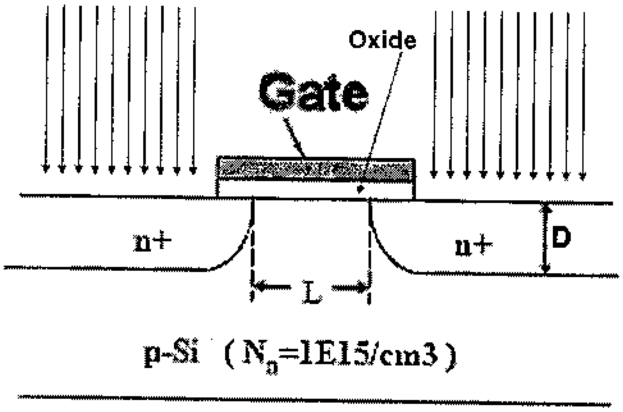
$$= \overset{162.1}{\cancel{92.16}} \left(5.6697 \times 10^{-12}\right)\left(\frac{W}{cm^2K^4}\right)\left(1273^4\right)\left(0.8\right)$$

$$\text{Power} = \cancel{1086.4}\ \text{watts}$$

$$\cancel{2414.2}$$

$$1931.4$$

Problem 3. (25 points total):



As an engineer for Intel, you are asked to develop a LDMOS (lateral diffused) MOSFET Transistor as shown to the right. The p-type bulk wafer concentration is 1×10^{15} cm^{-3} and the Gate is used as a "self aligned" implant mask having a gate width of 0.13 um. The implanter your company uses has a beam current of 5 µA. The n-type source and drain implant is performed first so the peak concentration is 1e20 cm^{-3} and is located at the surface and has a vertical straggle of 5 nm and a 10 nm lateral straggle resulting in a junction that extends under the gate as noted in the figure.

Note: To make the math easier, you can treat this problem like the implant is performed at two single points right at the edge of the gate (i.e. do not use the formula for a square aperture that involves complementary error functions but instead assume simple Gaussians). Additionally, treat this as only a 1D problem but NOT 2D or 3D. DO NOT USE THE PEARSON PROFILE – use the Gaussian profiles.

(a - 10 Points) What is the channel length L after implant?

(b – 15 Points) If a post implant anneal is performed, what characteristic diffusion length is needed to shrink the channel down to 65 nm?

a) $n(x) = n_0 e^{-(x-R_p)^2/2\sigma_\perp^2}$

$1e15 = 1e20\,\text{cm}^{-3}\, e^{-x^2/2(100\,\text{nm}^2)}$

Junction $\Rightarrow x = 48\,\text{nm}$

$L = 130\,\text{nm} - 2\times48\,\text{nm}$

$L = 34\,\text{nm}$

b) - $\boxed{\text{Can't get 65 nm Channel}}$ ←

Note: In test error gives above answer

Original # (intended problem) was for 32 nm channel.

$32\,\text{nm} = 130\,\text{nm} - 2x$

$x = 49$

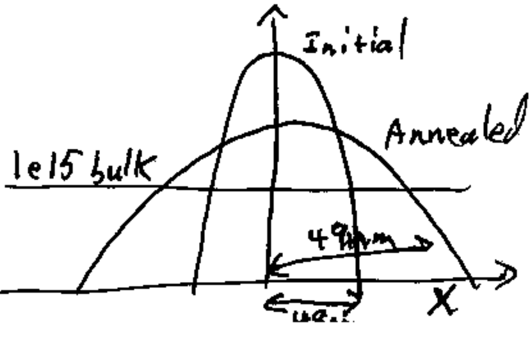
$\Downarrow$

$\sqrt{Dt} = 1\,\text{nm}$

Note: $n_0 = \dfrac{Q_T}{\sigma_\perp\sqrt{2\pi}}$

$\downarrow$

$\dfrac{Q_T}{\sqrt{\sigma_\perp^2+2Dt}\,\sqrt{2\pi}}$ makes negligible change



Problem 4. (35 points total):

AZ4620 photoresist is often used for thick photoresist films. It has the following set of Dill parameters at 365 nm:
A=0.3697 (1/um)
B=0.0243 (1/um)
C=0.0203 (cm^2/Joule)
When spun on at 1000 rpm, the resist is 20 um thick suitable for robust masks or thick films used in MEMS applications.

a) (10 Points) At an exposure intensity of ~~10~~ 100 milli-watts/cm^2, → for 18 sec how much [redacted] of the photoactive compounds have reacted with the light [redacted]?

b) (10 Points) Initially, when exposure first starts, what is the Intensity absorbed at the resist-substrate interface?

c) (10 Points) After all PAC is reacted [redacted], what is the Intensity absorbed at the resist-substrate interface?

d) (5 Points) Explain in 3 sentences or less why such a thick resist is designed to have such a small absorption coefficient at full exposure. You may want to draw a picture to help explain your thoughts.

1800 mJ/cm^2 a)

$$\alpha(z) = A\overset{\to \text{ Fraction of PAC unreacted}}{m} + B$$

$$m(z) = e^{-C\,\underbrace{t\,I(z)}_{\text{Dose}}}$$

$$m(z) = e^{-0.0203(18)(100e-3)}$$

$$m(z) = 0.964$$

$$\Rightarrow \frac{M}{M_0} = m \quad \Rightarrow \underline{\text{Only } 3.6\% \text{ of PAC Reacted!}}$$

b)
$$I = 100\,mW/cm^2\, e^{-\alpha(20um)} \quad \text{where } \alpha = A + B = 0.0.394\ 1/um$$

$$= 100\,mW/cm^2\, e^{-0.394(20)}$$

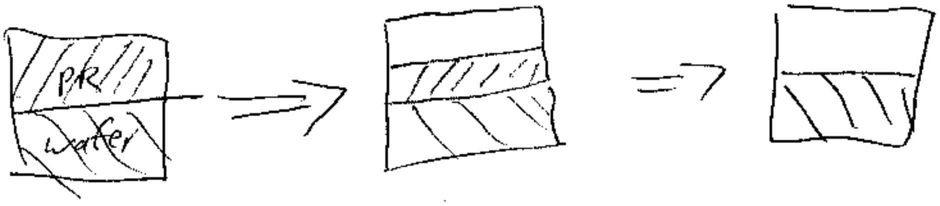
$$I\Big|_{20um} = 0.038\ mW/cm^2$$

c)
$$I = 100\, e^{-(0.0243)(20)} \qquad \alpha = A\cancel{m}^{0} + B = B$$

$$= 61.5\,mW$$

You may show your work here

d)



As the exposure continues the PR bleaches (becomes transparent) allowing a more uniform exposure.

Note: in reality the α changes very little because a very small percentage of the PAC reacts with the light.