

ECE 6450 Introduction to Microelectronics Technology

Exam 1

September 16, 2002

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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 sheet of notes (1 page front and back) as well as a calculator. There are 100 total points plus a chance for 10 bonus 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. (25 points total in 5-3 point parts):

True/False and Multiple Choice:

a.) Given that the energy bandgap of AlN is 6.2 eV, GaN is 3.4 eV and InN is ~0.8 eV, which material is likely to have the shortest chemical bonds?

- 1.) AlN
- 2.) GaN
- 3.) InN
- 4.) None of the above
- 5.) McDonalds is accepting applications for engineers who have no clue

b.) Which of the following are not considered point defects (may have more than one answer)?

- 1.) Vacancies
- 2.) Interstitials
- 3.) Dislocations
- 4.) Stacking faults
- 5.) Precipitates
- 6.) Grain Boundaries

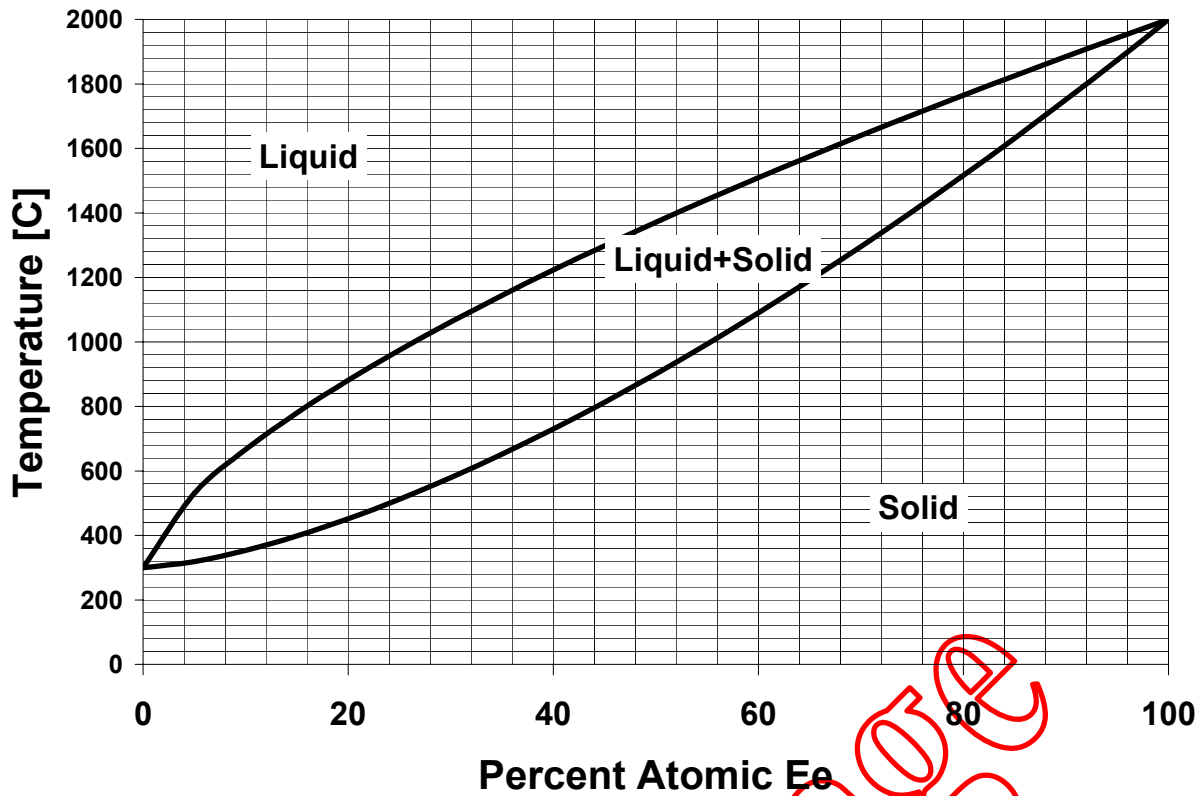
c.) Since a vacancy is really only a missing atom, it can have only a neutral charge?
True or False (circle the correct answer)

d.) Float Zone wafers are best for forming denuded zones because they have a very low oxygen content?
True or False (circle the correct answer)

e.) When a crystal is being grown by the CZ (Czochralski) method, the impurity concentration in the liquid is always the same as in the solid.
True or False (circle the correct answer)

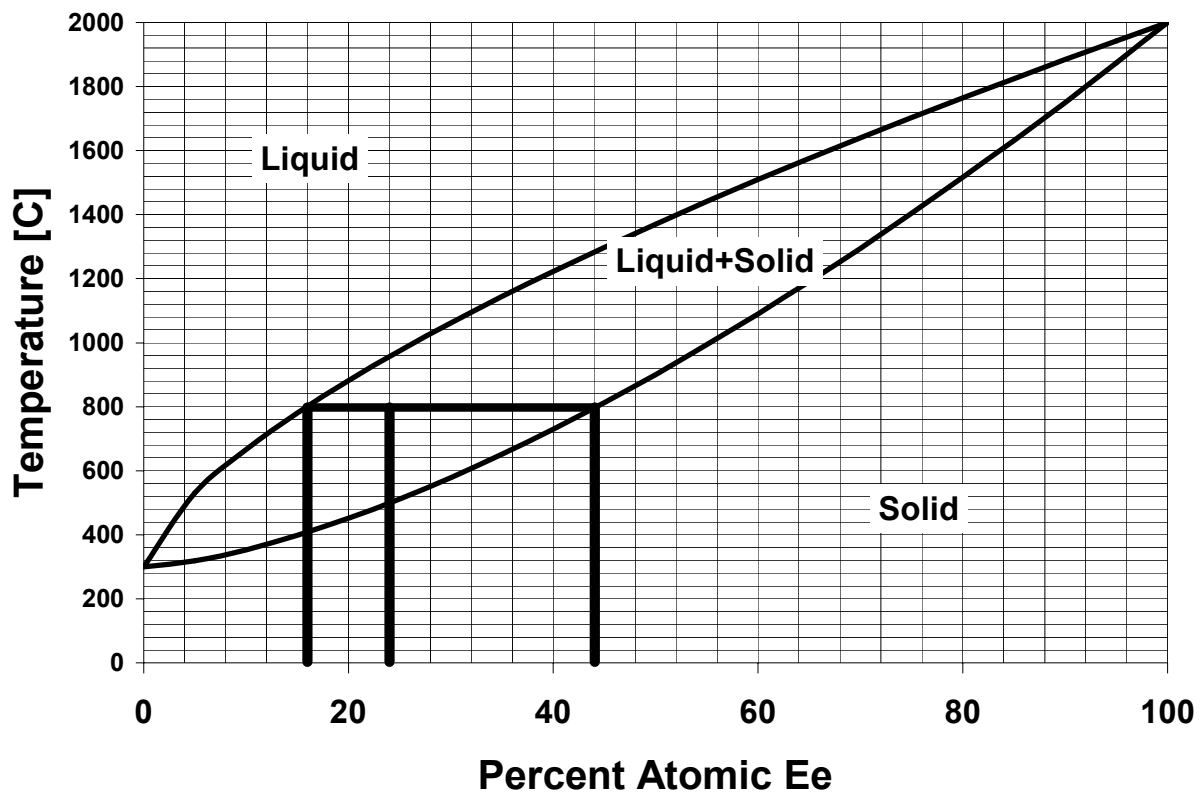
Problem 2. (25 points total):

Georgia Tech has developed a new material consisting of elements “Gt” and “Ee”. The phase diagram is shown for this material.



- A.) What is the melting point of Gt ?
- B.) What is the melting point of Ee ?
- C.) If a thoroughly mixed solution of 76%Gt and 24% Ee (atomic) are raised from room temperature to 800 degrees C, how much (%) of the material is solid?
- D.) What is the solid's concentration of Gt?
- E.) How much (%) of the material is liquid?
- F.) What is the liquid's concentration of Ee?

Problem 2:



- A.) 300 degrees C.
- B.) 2000 degrees C.
- C.)

$$\%Solid = 100x \frac{0.24 - 0.16}{0.44 - 0.16} = 28.6\%$$

- D.) 44% Ee or 56% Gt
- E.)

$$\%Liquid = 100x \frac{0.44 - 0.24}{0.44 - 0.16} = 71.4\%$$

- F.) 16% Ee

Problem 3. (25 points total+15 points bonus):

Arsenic is implanted with a single charge (As^+) into a p-type silicon wafer uniformly doped at 10^{16} cm^{-3} at low enough energy so that the implanted arsenic can be considered as existing in a two dimensional plane at the surface. Assume neutral vacancy controlled diffusion with $D_0=0.066 \text{ cm}^2/\text{sec}$ and $E_a=3.44 \text{ eV}$.

A.) Given that during the implantation, which lasted 6 seconds, the ion current density (I/Area) of $100 \text{ nA}/\text{cm}^2$, what is the dose supplied?

B.) If these impurities are driven into the wafer at 1200 degrees C, how much time is required to get a surface concentration of $5 \times 10^{16} \text{ cm}^{-3}$.

C.) What would be the concentration of Arsenic at a depth of $1 \mu\text{m}$ after the drive in.

10 point Bonus Question (All or no credit-i.e. no partial credit): If instead of the ion implant you had used a predeposition at 900 degrees C where the solubility of As in silicon is $5 \times 10^{19} \text{ cm}^{-3}$, what time would be required to get an identical dose?

A.) Dose is determined by ion implantation:

$$Q_T = \frac{1}{q \cdot \text{Area}} \int_0^{6 \text{ seconds}} I \, dx$$

$$= \frac{1}{q} \left(\frac{I}{\text{Area}} \right) \int_0^{6 \text{ seconds}} dx$$

$$= \frac{6 \text{ sec.}}{1.6 \times 10^{-19} \text{ C}} \left(\frac{100 \text{ nA}}{\text{cm}^2} \right)$$

$$Q_T = 3.75 \times 10^{12} \text{ cm}^{-2}$$

B.)

$$D = 0.066 e^{-\left(\frac{3.44 \text{ eV}}{(8.617 \times 10^{-5})(1200 + 273)} \right)}$$

$$= 1.12 \times 10^{-13} \text{ cm}^2/\text{sec}$$

$$C_s = \frac{Q_T}{\sqrt{Dx} \sqrt{\pi}}$$

$$5 \times 10^{16} \text{ cm}^{-3} = \frac{3.75 \times 10^{12} \text{ cm}^{-2}}{\sqrt{x} \sqrt{\pi} \sqrt{1.12 \times 10^{-13}}}$$

$$x = 1.6 \times 10^4 \text{ seconds or } 4.44 \text{ hours}$$

You may show your work here

$$c.) \quad C(x=1\mu\text{m}) = 5e16 e^{-\left(\frac{(1e-4)^2}{4(1.12e-13)(1.6e-4)}\right)}$$

$$C(x=1\mu\text{m}) = 1.2e16 \text{ cm}^{-3}$$

Bonus:

$$Q_T(x) = \frac{2}{\sqrt{\pi}} C(0,x) \sqrt{Dx}$$

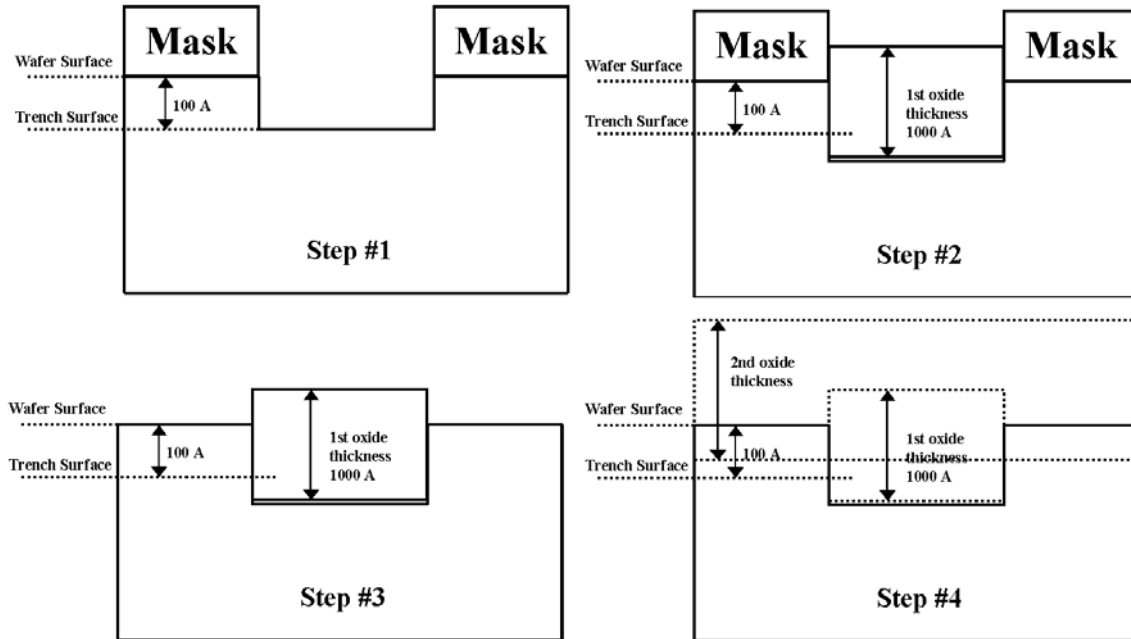
$C_s = 5e19 \text{ cm}^{-3}$

$$D = 0.066 e^{(-3.44/k(900+273))}$$
$$= 1.094 e-16 \text{ cm}^2/\text{sec}$$

$$3.75e12 = \frac{2}{\sqrt{\pi}} 5e19 \sqrt{1.094e-16} \sqrt{x}$$

$$x = 40.3 \text{ seconds}$$

F.) Problem 4. (30 points total):



Problem Statement:

A process is desired that oxidizes a region within a shallow trench of depth 100 angstroms as pictured above. The region outside of the trench is initially masked (see step #1 above) so that only the region in the trench is oxidized. We desire a high quality oxide of thickness 1000 angstroms, grown at 1000 degrees C within the trench region. After the high quality oxide is finished, the mask is removed (see step#3 above) and a fast, low quality oxide is to be grown at 1000 degrees C over all regions. The final result is to have a flat, planar oxide over the entire wafer (as shown above in step #4).

Assumptions:

Assume no lateral oxidation occurs (I.E. consider only the 1 dimensional case), the wet oxide parameters are valid for all regions, regardless of initial conditions, and the porosity and density of wet and dry oxides are the same. To answer this question you must know which oxide, wet or dry is of higher quality.

At 1000 degrees C:

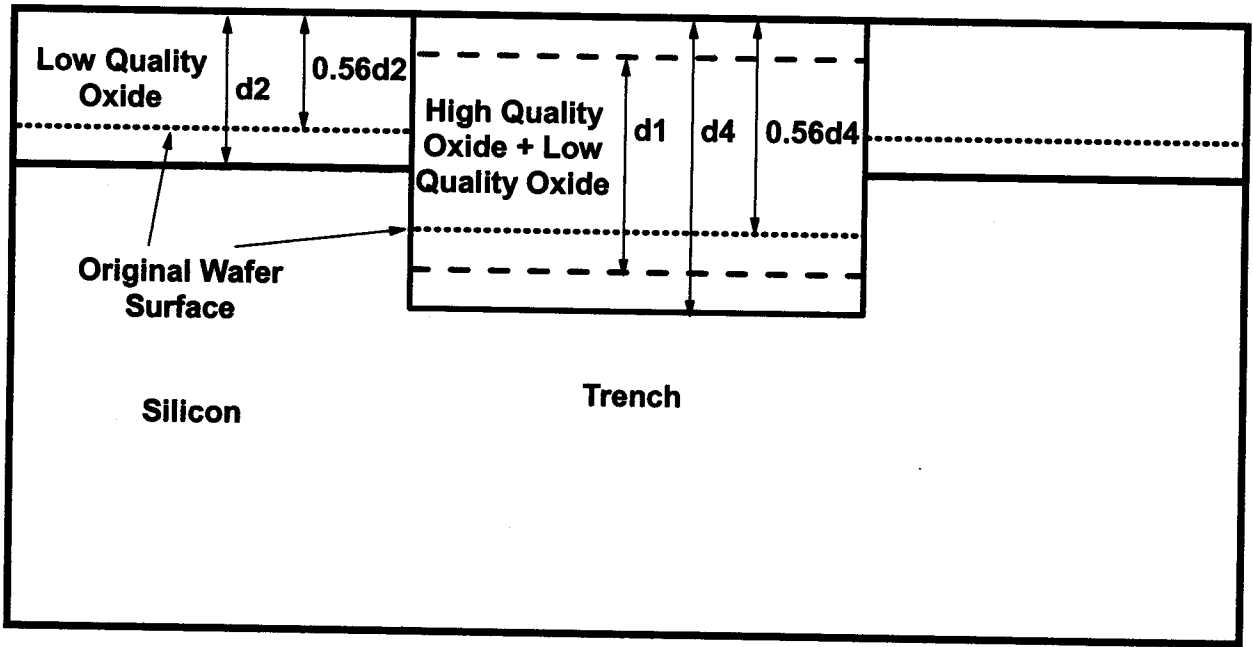
$A=0.165 \mu\text{m}$, $B=0.0117 \mu\text{m}^2/\text{hr}$ and $t=0.37 \text{ hr}$ for dry oxides

$A=0.226 \mu\text{m}$, $B=0.287 \mu\text{m}^2/\text{hr}$ for wet oxides.

- A.) What time is required to result in 1000 angstroms of high quality oxide inside the trench?
- B.) What time is required for the 2nd, low quality oxide such that the final surface is planar?
- C.) What is the low quality oxide thickness outside the trench?

SEE ANSWER

A.)



1st Oxidation: High quality implies dry oxidation while fast, low quality implies a wet oxidation. Thus,

$$t_1 = \left(\frac{d_1^2 + A_1 d_1}{B_1} - \tau_1 \right) = \left(\frac{(0.1 \mu m)^2 + 0.165(0.1 \mu m)}{0.0117} - 0.37 \right) = 1.89 \text{ hours} \quad (1)$$

B.)

Now for the second oxidation,

Planarity Constraint:

Define $d_3 = (d_4 - d_1)$ or $d_4 = (d_1 + d_3)$ where d_1 is the high quality oxide thickness after the initial oxidation, d_4 is the total oxide thickness after the both oxidations. Define d_3 as the additional oxide thickness added during the 2nd, wet oxidation.

Define d_2 as the low quality oxide thickness.

Since the amount of silicon consumed during oxidation is 0.44 times the oxide thickness, the planarity constraint is,

$$0.56d_2 = 0.56d_4 - 1e-2 \mu m \quad \text{or} \quad d_2 + \frac{1e-2 \mu m}{0.56} = d_4 \quad (2)$$

↑
Trench depth

In the Trench:

$$\frac{d_4^2}{B_2} + \frac{A_2 d_4}{B_2} = t_2 + \tau_2 \quad (3)$$

Where τ_2 is the time shift defined by the preexisting oxide from the first diffusion.

$$\tau_2 = \frac{(0.1)^2 + 0.226(0.1)}{0.287} = 0.113 \text{ hours} \quad (4)$$

Using (2) in (3) we get,

$$\frac{\left(d_2 + \frac{0.01}{0.56}\right)^2}{0.287} + \frac{0.226\left(d_2 + \frac{0.01}{0.56}\right)}{0.287} = t_2 + 0.113 \quad (5)$$

Outside the Trench:

Similarly because of no preexisting oxide outside the trench,

$$\frac{(d_2)^2}{0.287} + \frac{0.226(d_2)}{0.287} = t_2 \quad (6)$$

Subtracting (6) from (5), we get,

$$\left(\frac{2d_2(0.01)}{0.56(0.287)}\right) + \frac{(0.01)^2}{0.287(0.56)^2} + \frac{0.226(0.01)}{0.287(0.56)} = 0.113 \quad (7)$$

$$\text{or } d_2 = 0.786 \mu m$$

Thus, from (6) we get,

$$t_2 = 2.77 \text{ hours} \quad (8)$$

C.) From (7) and (2) above,

$$d_2 = 0.786 \mu m \quad d_4 = 0.804 \mu m$$