FYS4310 Quick Quiz 2. Time : 90 min, Help items: Std. Physical Tables, Calculator
Obligatory delivery, No grading. Make a print-out of the test and deliver to Terje, notify by email tgf@fys.uio.no that you have delivered it, no need for sudent identity or name on test.

1.

For ion implantation of different ions into different substrates;

a) At 100 keV, which case will have the largest range

- I) ☐ Si^+ in Ge at RT
- II) ☒ Ge^+ in Si at RT
- III) ☐ case a.I and a.II will have practically the same range

b) For Zn in InSb, which case will have the largest range

- I) ☐ implanted Zn^+ at 50 keV at RT
- II) ☒ implanted Zn^- at 50 keV at RT
- III) ☐ case c.I and c.II will have practically the same range

c) For 60 keV B^+ in Si at RT, mark the case closest to the projected range

- I) ☐ 2 nm
- II) ☐ 20 nm
- III) ☐ 200 nm
- VI) ☐ 2 μm
- V) ☒ 20 μm

d) For 60 keV As in Si at RT, mark the case closest to the projected range

- I) ☐ 4.5 nm
- II) ☒ 45 nm
- III) ☐ 450 nm
- VI) ☐ 4.5 μm
- V) ☐ 45 μm

e) For implantation in ZnO, which case will have the largest projected range

- I) ☒ A H^+ion at 10 keV at T=RT
- II) ☐ A Li^+ion at 50 keV at T=RT
- III) ☐ A Cs^+ion at 70 keV at T=RT

g) For implantation of 1 MeV H^+ in Si at RT

- I) ☒ An amorphous layer will be created for a dose of $1x10^{15}$ ions/cm^2
- II) ☐ An amorphous layer will not be created for a dose of $1x10^{15}$ ions/cm^2

2.

When growing an oxide on Si by thermal oxidation the growth of the layer can be limited by diffusion or by reaction. For purely diffusion limited growth the thickness varies with time, *t*, as alternative a) ..e), where *k* is a parameter independent of *t*.) Check the correct answer (with X)

- **a).** $k*t$ ☒
- **b)** $\ln(k*t)$ ☐
- **c)** $\exp(-k*t)$ ☐
- **d).** k ☐
- **e)** $k*t^{1/2}$ ☐

3.

Assume that the projected range of Sb^+ in Si is 20 nm for 40 keV implantation.

a) Make an estimate of the value of the nuclear stopping power $(dE/dx)_n$ ....1000....

b) Make an estimate of the value of the electronic stopping power $(dE/dx)_e$ ....200....

c) If the mean displacement energy of Si is 26 eV, then estimate how many vacancies does one ion create. vet ikke

4.

Rapid Thermal Annealing is used to activate implanted species and to anneal out damage.

a) Give a rough number for a typical time, t, used in rapid thermal annealing.

$t =$ 60 s

b) Can this in general be achieved by regular furnace annealing in a quartz tube used for drive-in diffusion? Nei

c) Explain the relation between a) and b)

RTA krever at et substrat blir hurtig oppvarmet (og nedkjølt). Dette er ikke mulig med vanlige ovner, Man trenger spesielle ovner (med lampe

5.

The growth rate of a layer amorphized by ion implantation of <100>Si is well described by $r=r_0*\exp(-E_a/kT)$ where E_a is around 2.3 eV. Give an estimate of r_0 (in units cm/s).

$r_0 =$ 10^{8} assuming that each atom make an activated jump with activation energy E_a to "fall into place" in the lattice. Comment in the space below,

Jeg antar da at r_0 er omtrent lik gitter-distansen, siden hvert atom skal falle på plass

6.

What is "emitter push"? Explain in the space provided below.

Skjer når den dopete emitter-regionen diffunderer inn i dopet base-region. Emitter-regionen er veldig høyt dopet.

7.

Below are several statements that can be either true or false. Indicate by ***T*** for true and ***f*** for false

a) .***T***. This line has already been solved, showing you how to do it

b) .T..When implanting boron at 100 kev in Si, the implantation profile is skewed compered to a Gaussian profile and it will have a most probable projected range deeper than the mean projected range.

c) ...T.. The Bolzman-Matano method is a numerical method for solving the diffusion equation.

d) ..F... SUPREME III is a program for calculation of the electronic structure of super lattices of semiconductors and metals.

e) ..T... During thermal oxidation of Silicon at 900 °C for one hour most dislocations within 5 μm of the original surface will disappear/anneal out.

f)..F....The solid solubility of As in Si is normally higher than the doping concentration
g)..F... Two stage annealing can induce stacking faults in ion implanted Si and is not performed in production.
h)..T... The sensitivity for an element in SIMS analysis depends upon the matrix.
i)..T. A polishing etch for Si is usually much slower in the <111> direction than in the <100> direction.
j)..T....The sputter coefficient for Cl^+ ions is ten times higher for Si than for SiO_2.
k)..F.. The sputter coefficient will usually be lower for an ion (1-500 keV) hitting a surface parallel to the surface normal than one making an angle of 45 degree.
l)..T.... The pressure unit "1 atm" is the same as "760 torr".
m)..T....An ion pump can be used to pump down a vacuum chamber from 1 atm to 10^{-5} torr.
n)...F...An ion gage vacuum sensor can read the pressure from 10^{-5} to 10^{-11} torr.

8.

The displacement energy, E_d, is the energy an atom has to receive from a collision in order to be knocked out of it's lattice position(to create a vacancy or a substitutional). In ZnO it is tabulated that E_d is 50 eV and 55 eV for displacement of Zn and O atoms respectively. Assume we irradiate ZnO by 20 keV electrons. We may then expect to have

a) ☒ About the same number of Zn vacancies and O vacancies
b) ☐ More, about 10 % , Zn vacancies than O vacancies
c) ☐ More, about 10 % , O vacancies than Zn vacancies
d) ☐ Only Zn vacancies.
e) ☐ Only O vacancies.

9.

List some potential problems that may arise if the vacuum in an ion implanter becomes too poor, and give an approximate value in torr for what is a poor vacuum.

10^{-4} torr og opp til standard atmosfære virker som dårlig vakuum

Problemer med dårlig vakuum kan være at man sender ioner (akselerert) mot et mål for å forandre målets komposisjon. Med dårlig vakuum får man utilsiktet komposisjon fordi det er urenheter der som ikke skal være der.