FYS4310

Oblig 1

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Problem 200-8

Vacancy concentration is given by (2.1 in book)

$$N_v^0 = N_0 \exp\left(\frac{-E_a}{kT}\right)$$

Where ; N_v^0 is vacancy concentration

N_0 is number density of atoms (5.02×10^{22} cm^{-3} for silicon)

E_a is activation energy for vacancy creation (2.6 eV for silicon)

k is boltzmann's constant $= 8.617 \times 10^{-5}$ eV. K^{-1}

T absolute temperature.

(a) N_v^0 for Si at 1100°C

i.e. $T = 1373$ K

So, $N_v^0 = 5.02 \times 10^{22}$ cm^{-3} $\exp\left[\frac{-2.6\ \cancel{eV}}{8.617 \times 10^{-5} \times 1373\,\cancel{K}.\cancel{K^{-1}}.\cancel{eV}}\right]$

$= \underline{\underline{1.434 \times 10^{13}\ \text{cm}^{-3}}}$

(b) N_v^0 for Si at room temperature i.e. $T = 300$ K

$N_v^0 = 5.02 \times 10^{22}$ cm^{-3} $\exp\left[\frac{-2.6\ \cancel{eV}}{8.617 \times 10^{-5}\ \cancel{eV}.\cancel{K^{-1}}.\ 300\ \cancel{K}}\right]$

$= \underline{\underline{1.049 \times 10^{-21}\ \text{cm}^{-3}}}$

! not even 1 vacancy per cm^3 at room temperature

Problem 200-10

When we see pictures of the steps from growth to wafers, we notice that the crystal is pulled in a particular direction.

(a) In order to achieve this, first we need to decide the required crystallographic direction of crystal growth. Then during growth, the direction of seed crystal can be aligned to appropriate orientation to get the crystal growth in desired crystallographic direction.

(b) There can be many reasons for growing crystal in particular direction. Some of them are;

→ different crystal planes can have different atom density and dopant density. This affects the electrical and thermal properties of crystal.

→ different crystal planes can have non-uniform response to various unit processes like deposition, diffusion, etching, etc. So it is important to choose the right crystallographic plane to get desired response of unit processes

(c) OK. I will answer this question again after I have completed this course. I assume that I will have a better answer

Problem 200-20

The oxygen content of Si crystal usually decreases from the seed towards the bottom of the crystal. This can be explained using equation (2.13) from book

$$C_s = k C_0 (1-X)^{k-1}$$

where C_s concentration of dopant in solid.

C_0 initial concentration of dopant in melt

k segregation coefficient

X fraction of melt that has solidified.

This equation tells us that with the increase in the fraction of boule, the concentration of dopant in solid decreases.

Hence oxygen content of Si crystal usually decreases from the seed towards the bottom of crystal.

! But the actual decrease in oxygen concentration may not be as much as given by above equation in CZ because supply of oxygen is constantly renewed and it will be approximately constant along the length of boule

[textbook, Pg 26, second paragraph]

Problem 1400-3

(a) (b) and (c)

	Temp.	h_g	E_a.	K_o.
SiH_4	$900^\circ C$	$0.9\ \mu m/min$	$\approx 1.45\ eV$	$\approx 0.551\ \mu m/min$
SiH_2Cl_2	$940^\circ C$	$0.5\ \mu m/min$	$\approx 1.45\ eV$	$\approx 0.533\ \mu m/min$
$SiHCl_3$	$960^\circ C$	$0.45\ \mu m/min$	$\approx 1.45\ eV$	$\approx 0.134\ \mu m/min$
$SiCl_4$	$1080^\circ C$	$0.18\ \mu m/min$	$\approx 1.45\ eV$.	$\approx 0.053\ \mu m/min$

Where;

Temp : temperature where growth becomes mass transport limited

h_g : mass transport coefficient

E_a : reaction activation energy (See attachment for its calculation)

K_0 : reaction coefficient at absolute zero given as

$$K_0 = K_s \exp\left(\frac{E_a}{kT}\right)$$

Problem 1400-3.

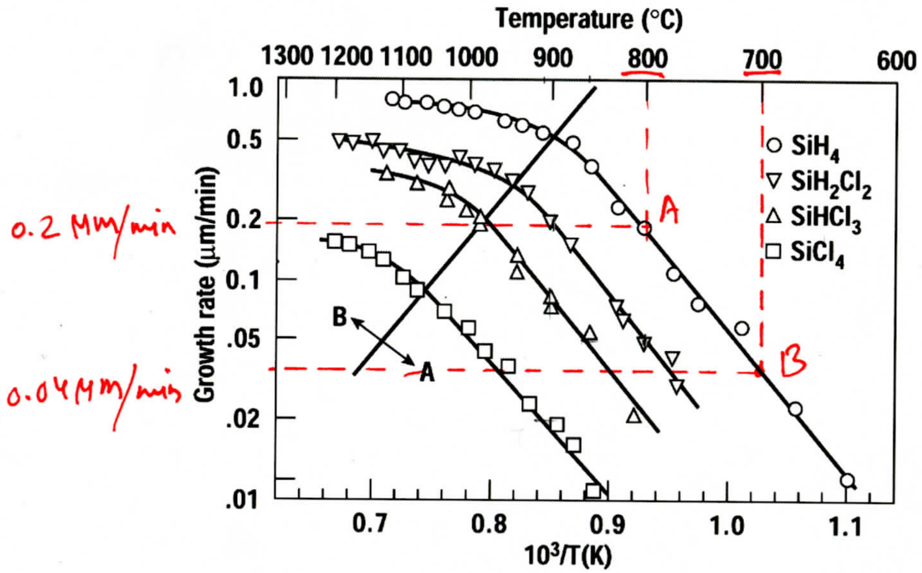

Figure 14.8 Arrhenius behavior of a variety of silicon-containing growth species *(after Eversteyn, reprinted by permission, Philips).*

With the use of this figure and the model do the following

a) Identify, for each molecule, the approximate temperature where the growth becomes mass transport limited.

b) Find for each molecule h_g

c) Find for each molecule k_0 and E_a

PROBLEM 1400-4 (Si epi growth, surface, easy(=14.4 in book))

An epitaxial growth chamber has a background O_2 pressure of 2x10-5 torr. What would be the minimum annealing temperature to ensure a Si-stable surface if only the background gases are present? Alternatively, one can flow H_2, which contains 5 ppb of O_2. If this gas flushes the chamber of its background contaminants, what would be the minimum annealing temperature be at 760 torr of H_2. ?

To find E_a for SiH_4.

At A: $0.2\ \mu m/min = k_0 \exp\left(\frac{-E_a}{k \cdot 1073}\right)$ —(i)

At B: $0.04\ \mu m/min = k_0 \exp\left(\frac{-E_a}{k \cdot 973}\right)$ —(ii)

Dividing (i) and (ii)

$$\frac{0.2}{0.04} = \exp\left(\frac{E_a}{k\,973} - \frac{E_a}{k \cdot 1073}\right)$$

or, $k \cdot \ln(5) = \frac{E_a}{973} - \frac{E_a}{1073}$

or, $E_a = 1.68 \times 10^4 \times 8.617 \times 10^{-5}$ eV

$\approx \underline{1.45\ eV}$

! E_a is almost same for all because their slope in reaction limited regim is almost same.

Problem 200-5

Figure (14.6) in the textbook shows the silicon growth rate as a function of $SiCl_4$ flux.

The plot shows that when the concentration of $SiCl_4$ exceeds 0.26 mol fraction in H_2, the growth rate is negative which means silicon is etched from the surface of substrate. It is because with higher $SiCl_4$ flux, a lot of gaseous HCl is produced which causes deposited silicon to etch.