Suggested Solution problem 1400-1, FYS3410/9310

Problem text:

A silicon epitaxial growth process is attempted with a chamber temperature of 1050 °C. We have flows of 200 sccm $SiCl_4$ and 100 sccm of Si_2H_6. Assume that the mixture attains chemical equilibrium. What is the supersaturation in the chamber? Will these conditions grow an epitaxial layer or etch? If the temperature is increased to 1300 °C, by what percentage would you expect the growth (or etch) rate to increase or decrease?

The unit **sccm** stands for **standard cubic centimeters per minute**

So it is a flow rate; if we assume ideal gass behavior, then all gasses with the same flow rate correspond to equal number of gas molecules and so equal partial pressure.

Some info…

The **super saturation** is defined by

$$\sigma = \left[\frac{p_{Si}}{p_{Cl}}\right] - \left[\frac{p_{Si}}{p_{Cl}}\right]_{(eq)}$$

The reaction with $SiCl_2$ gas is

$Si(s) + 2HCl(g) = SiCl_2(g) + H_2(g)$

When the reaction goes to the left we grow while when it goes to the right we etch. It is reflected in the magnitude of the equilibrium constant (the constant of mass law action)

$$\frac{[Si(s)][HCl(g)]^2}{[SiCl_2(g)][H_2(g)]} = K_p(T)$$

We will have other reactions as well, for example

$Si(s) + 4HCl(g) = SiCl_4(g) + 2H_2(g)$

If the HCl concentration increases , the growth would be slower, or we have etching OK, so we may have very many different gases present for all chlorosilane feed gases, the actual equilibrium pressure between them may not be reached, but it is considered that at low atomic percentages of the feed gases $SiCl_2$(dichlorosilane) is the primary growth specie.

We evaluate the temperature 1050 °C = 1323 K

The feedgas is 200 sccm $SiCl_4$ and 100 sccm Si_2H_6

The Si/Cl ratio of the given feed gas is

$$\frac{Si}{Cl} \propto \frac{200\cdot 1 + 100\cdot 2}{200\cdot 4} = 0.5$$

The Cl/H ratio is

$$\frac{Cl}{H} \propto \frac{200\cdot 4}{100\cdot 6} = 1.33$$

The equilibrium Si/Cl ratio can then be read off Fig 14.7 Procedure next page

Procedure

1. Locate the point 1.33 on the left Y axis for the Cl/H ratio
2. Draw a horizontal line until crosses temperature1323 K
3. Follow the curved line going through that point towards the right Y axis.
4. Read off the equilibrium Si/Cl ratio corresponding to the Cl/H ratio 1.33
5. I read off approximately 0.275.

So the supersaturation is 0.5 – 0.275 = 0.225 > 0 So we will grow,
(NB the supersaturation is high, we are relatively far from equilibrium, [GaAs MBE more so])

Increase the temperature to 1300 C – 1573 K
I get a 0.30 in equilibrium ratio, so the supersaturation is not changed much.
If the growth rate is prop. to supersaturation, it will be 1.125 higher. We are in the transition from mass transport limited regime to reaction limited growth. For transport limited growth it is the same for all supersaturations, for reaction ilimited growth it varies with supersaturation.(fig 13.8 lecture note)