EE 243: ADVANCED IC PROCESSING AND LAYOUT

Sp 2008

Homework Assignment #8 (Due April 16, Wed)

Reading Assignment :
PDG Chapter 9
Lec Notes

Problem 1 Vacuum Units and CVD Deposition Parameters

A CVD tube reactor operating at 1 atmospheric pressure has a cross-sectional area of 50 cm^2 .
The input gas mixture is 2% $SiCl_4$, 98%H_2 by volume.
The total input gas flow rate is 1.5 liters/min at room temperature.
The temperature in the reaction zone is 1250°C with the viscosity of the gas mixture = 3×10^{-4} gm/cm-sec.

(a) Assuming flow velocity is uniform across the tube cross-section, estimate the gas stream velocity U at the reaction zone.

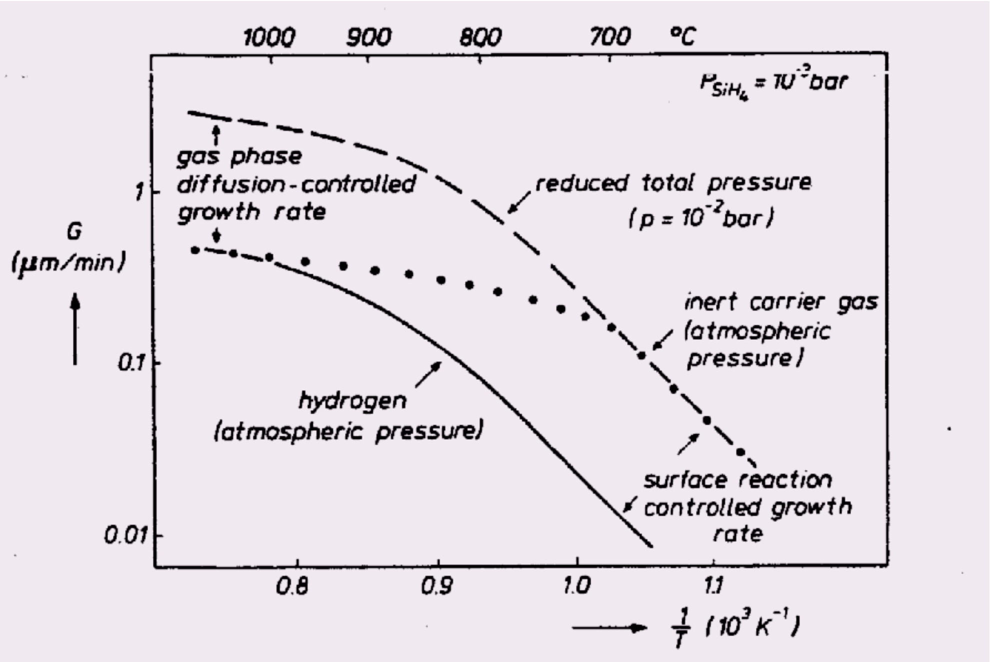
(b) Calculate the Reynolds number ($\frac{\rho U L}{\mu}$) for a 3-inch diameter wafer inside the reactor tube.

(c) Calculate the concentration of $SiCl_4$ in the reacting zone (in molecules/cm^3)

(d) Estimate the Si film growth rate, assuming the growth process is ***mass-transfer limited*** and the gas diffusivity D_G is ≈ 8 cm^2 /sec .

Problem 2 CVD Deposition Rate - Effect of Carrier Gas

Poly-Si deposition by pyrolysis of silane will have deposition rate dependence on both the carrier gas and the total pressure. The deposition rates versus 1/T are shown in the following figure. In this experiment, the partial pressure of silane is **fixed** at 10^{-3} bar **The dash and solid lines are having hydrogen as the carrier gas**. It is known that hydrogen suppresses the surface reaction for silane pyrolysis. **The dotted line is having nitrogen as the carrier gas** which does not suppress surface reaction .



(i) There is no difference between nitrogen or hydrogen as carrier gas on deposition rate **at high temperatures**. Explain.

(ii) There is a difference between nitrogen or hydrogen as carrier gas on deposition rate **at low temperatures**. Explain.
(iii) Discuss the the difference between the dotted curve and dash curve for all temperature range.

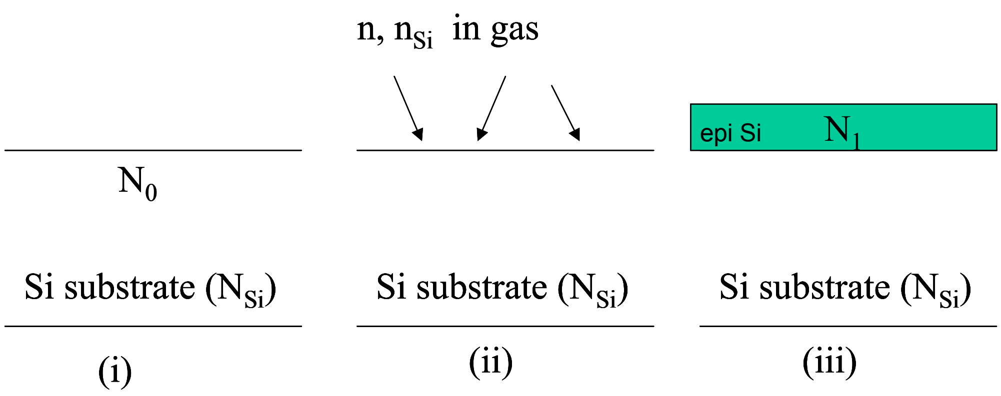
Problem 3 Evaporation

Gold is evaporated in the Microlab using 30 cm between the evaporator boat and a 100 mm wafer centered above the boat.

a) What vacuum pressure is needed such that a gold atom will only have a 0.05 probability of collision in reaching the wafer? [Probability = $\exp(-z/\lambda)$ where λ is the mean free path.]
b) If the evaporation has a $\cos\theta$ emission factor, what volume of gold must be evaporated to deposit 1 μm of gold at the center of the wafer? [At $1000/oz , what is the cost of this evaporation?]
c) If the evaporation takes 10 seconds and uses an area $A_{Source} = 0.25\ cm^2$, what average vapor pressure was achieved?
d) What will be the gold thickness at the edge of the wafer?

Problem 4 Autodoping concentration profile during Epitaxial Growth

The following simple autodoping model for epitaxial growth of Si ignores solid state outdiffusion and the growth process is considered as discrete steps.



For step (i) $[\text{dopant}]_{solid} / [\text{Si}]_{solid} = N_o / N_{Si}$ where [ ] denotes concentration ,
N_o = dopant atomic density at surface initially,
N_{Si} = Si atomic density.
For step (ii) , $[\text{dopant}]_{gas} / [\text{Si}]_{gas} = (N_o + b\,n) / (N_{Si} + b\,n_{Si})$
where n and n_{Si} are atomic densities of dopant and Si in the incoming gas stream respectively.
With some thinking, you can show that :
b = B . (atomic density in solid phase) / (atomic density in gaseous phase) where B is a gas transport constant.
For step (iii), $[\text{dopant}]_{solid} / [\text{Si}]_{solid} = N_1 / N_{Si} = (N_o + b\,n) / (N_{Si} + b\,n_{Si})$ with N_1 being the new surface dopant atomic density.
The cycle then repeats with the new surface concentration being N_2, N_3,..., N_k ,.... etc.. It should be noted that n and n_{Si} remain constant throughout the epi CVD process.
(a) Show that after k cycles , the surface dopant concentration is given by :
$N_k = N_o \alpha^k + [\alpha b\,n (1 - \alpha^k) / (1 - \alpha)]$ where $\alpha = N_{Si} / (N_{Si} + b\,n_{Si})$
(b) In each cycle, let a layer of thickness h be grown. Show that the dopant profile as a function of distance from the interface , x, can be represented by :
$N(x) = N_o \exp\{-\phi x\} + [\alpha b\,n (1 - \exp\{-\phi x\}) / (1 - \alpha))$
(c) How is the parameter ϕ related to h and α ?