

Homework #7 Solutions

9.5. For CVD deposition of a film, it is found that the mass transfer coefficient $h_G = 10.0 \text{ cm sec}^{-1}$ and the surface reaction rate coefficient $k_s = 1 \times 10^7 \exp(-1.9 \text{ eV}/kT) \text{ cm sec}^{-1}$. For a deposition at 900°C , which CVD system would you recommend using: (a) a cold-walled, graphite susceptor type or (b) a hot-walled, stacked wafer type? Explain your answer.

Answer:

At 900°C ,

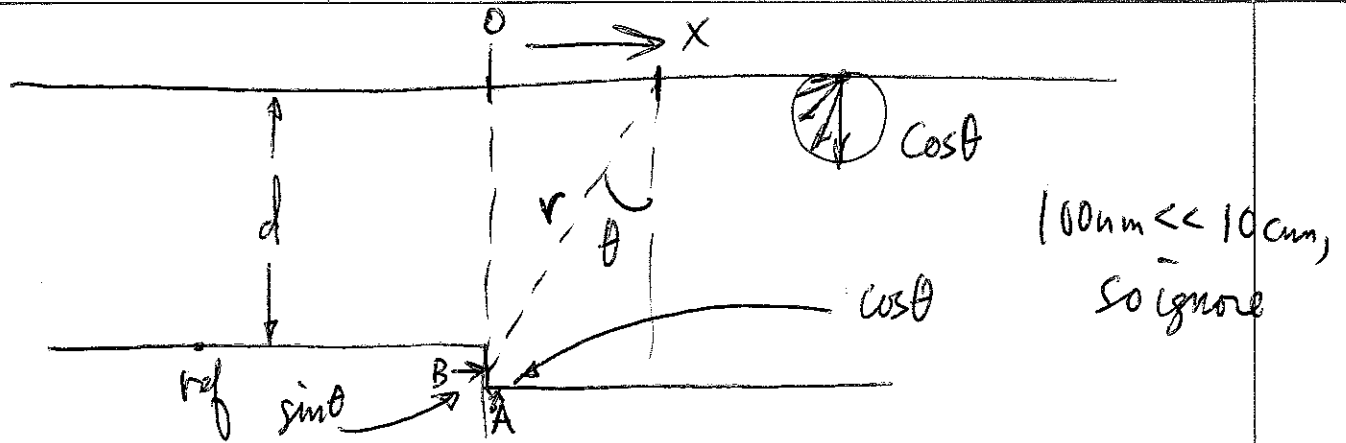
$$k_s = 1 \times 10^7 \exp\left(\frac{-1.9 \text{ eV}}{kT}\right) \text{ cm} \cdot \text{sec}^{-1} = 1 \times 10^7 \exp\left(\frac{-1.9 \text{ eV}}{8.62 \times 10^{-5} \frac{\text{eV}}{\text{K}} 1173 \text{ K}}\right) \text{ cm} \cdot \text{sec}^{-1}$$

$= 0.069 \text{ cm sec}^{-1}$. This is much less than h_G (10.0 cm sec^{-1})

Therefore $k_s \ll h_G$. This means that the system will be in the surface reaction controlled regime. The transfer of species through the boundary layer in the gas phase is fast and not important relative to the surface reaction. Therefore you can stack the wafers without causing uniformity problems due to gas transport variations, and achieve maximum throughput. In this regime, the deposition rate is sensitive to temperature, but in a hot-walled system, good temperature control can be achieved. Thus you should recommend using (b) a hot-walled, stacked wafer type system.

Note: We are assuming here that the mass transfer is still very fast relative to the reaction rate when the wafers are in a stacked configuration. However, with the stacked configuration, the reactants must travel from the gas stream to each position on the wafer through a stagnant layer between the wafers, and the value of h_G would decrease the further they must travel. For larger size wafers, h_G thus becomes smaller and the mass transfer of reactants becomes more difficult, even at lower pressure, than for smaller wafers. In that case the spacing between the wafers may need to be increased, or the pressure reduced, to ensure reaction limited conditions and uniform deposition.

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(a) In 2D system (infinite into page), flux goes at $\frac{F_0}{2\pi r}$

$$\frac{F_A}{F_{ref}} = \frac{\int_0^{\infty} \frac{F_0}{2\pi r} \cos^2(\theta) dx}{\int_{-\infty}^{\infty} \frac{F_0}{2\pi r} \cos^2(\theta) dx} = \frac{1}{2} \text{ by symmetry}$$

(b)

$$\frac{F_B}{F_{ref}} = \frac{\int_0^{\infty} \frac{F_0}{2\pi r} \cos\theta \sin\theta dx}{\int_0^{\infty} \frac{F_0}{2\pi r} \cos^2\theta dx}$$

$x = d \tan\theta$
 $dx = \frac{d}{\cos^2\theta} d\theta$
 $d = r \cos\theta$

$$= \frac{\int_0^{\pi/2} \frac{F_0}{2\pi} \frac{\cos\theta \sin\theta}{d/\cos\theta} \frac{d}{\cos^2\theta} d\theta}{\int_{-\pi/2}^{\pi/2} \frac{F_0}{2\pi} \frac{\cos^2\theta}{d/\cos\theta} \frac{d}{\cos^2\theta} d\theta} = \frac{\int_0^{\pi/2} \sin\theta d\theta}{\int_{-\pi/2}^{\pi/2} \cos\theta d\theta}$$

$$= \frac{-\cos\theta \Big|_0^{\pi/2}}{\sin\theta \Big|_{-\pi/2}^{\pi/2}} = \frac{-(0-1)}{1-(-1)} = \frac{1}{2}$$

3 (a) The initial SiH₄ concentration is (using concentration under standard conditions),

$$\left(\frac{2 \text{ slpm}}{2 \text{ slpm} + 6 \text{ slpm}} \right) \frac{0.5 \text{ Torr}}{760 \text{ Torr}} \left(\frac{298}{600 + 273} \right) 2.47 \cdot 10^{19} \text{ molecule cm}^{-3}$$

$$\underline{1.386741123 \cdot 10^{15} \text{ molecule}} \quad (1)$$

$$\text{cm}^3$$

Thus, the initial rate of surface reaction is

$$\frac{1.39 \cdot 10^{15} \text{ molecule}}{\text{cm}^3} \cdot 5 \cdot 10^8 \text{ e}^{\left(\frac{-1.6}{873 \cdot 8.62 \cdot 10^{-5}} \right)} \frac{\text{cm}}{\text{s}}$$

$$\underline{4.056350373 \cdot 10^{14} \text{ molecule}} \quad (2)$$

$$\text{cm}^2 \text{ s}$$

and the deposition rate is

$$\frac{4.06 \cdot 10^{14} \text{ molecule}}{\text{cm}^2 \text{ s} \cdot 5 \cdot 10^{22} \text{ molecule cm}^{-3}}$$

$$\underline{8.120000000 \cdot 10^{-9} \text{ cm}} \quad (3)$$

$$\text{s}$$

(b) Each cm, the surface area is

$$2 \text{ wafer} \cdot \frac{2 \text{ side}}{\text{wafer}} \cdot \frac{3.14 \cdot (20 \text{ cm})^2}{\text{side}} + (1 \text{ cm}) \cdot 2 \cdot 3.14 \cdot (25 \text{ cm})$$

$$\underline{5181.00 \text{ cm}^2} \quad (4)$$

Thus, in each cm,

$$5181 \text{ cm}^2 \cdot \frac{4.06 \cdot 10^{14} \text{ molecule}}{\text{cm}^2 \text{ s}}$$

$$\underline{2.103486000 \cdot 10^{18} \text{ molecule}} \quad (5)$$

$$\text{s}$$

of SiH₄ is used up and twice that amount of H₂ is generated. Therefore,

$$\frac{2.1 \cdot 10^{18} \text{ molecule}}{\text{s cm}} \cdot \left(1 + 2 \cdot \frac{2}{6} \right)$$

$$\underline{3.500000000 \cdot 10^{18} \text{ molecule}} \quad (6)$$

$$\text{s cm}$$

of SiH₄ needs to be added to keep the same relative concentration (and thus same absolute concentration at constant pressure). This is

$$\frac{3.5 \cdot 10^{18} \text{ molecule}}{\text{s cm}}$$

$$\frac{2.47 \cdot 10^{22} \text{ molecule}}{60 \text{ s} \cdot \text{slpm}}$$

$$\underline{0.008502024291 \text{ slpm}} \quad (7)$$

$$\text{cm}$$