## EECS 243 – Advanced IC Processing and Layout

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# Solution Assignment # 6

**6.1 Vacuum basics**

a) $\sigma = \pi r^2 = \pi(3\text{x}10^{-8})2 = 2.83\text{x } 10^{-15}\text{ cm}^2$ $n = [6.02\text{x}10^{23})/22.4\text{l}](10^{-3})\ [10^{-5}/760](273/298) = 3.27\text{x}10^{11}$ $\lambda = 1/(n\sigma) = 10.7\text{m}$
b) $c = (8kT/\pi m)^{1/2} = [( 8 \text{ x } 1.38\text{x}10^{16} \text{ x } 298)/(\pi \text{ x } 39.94 \text{ x } 1.66\text{x}10^{-24})]^{1/2} = 3.97\text{x}10^4$ cm/s
$nc/4 = 3.29\text{x}10^{11} \text{ x } 3.97\text{x}10^4 /4 = 1.3\text{x } 10^{16}$ atoms/cm$^2$s $n_{SUB} = N_o\rho/GMW = 6.02\text{x}10^{23} \text{ x } 1.78/39.94 = 2.68\text{x}10^{22}$ $v = F/n_{SUB} = 1.3\text{x}10^{16}/2.68\text{x}10^{22} = 4.8$ nm/s
c) Fraction = 4.8 nm/s/(10 nm/s + 4.8 nm/s) = 0.32 (even though $\lambda$ = 10 meters!)
d) $R_{WAFER}$ = Area x rate x density = 78.5 cm$^2$ x $10^{-6}$ x 2.7 = $2.12\text{x}10^{-4}$ gm/s = $R_{EVAP}$
Guess based on Figure 9.20 of PDG00 that T=1100 $^o$C and substitute to find $P_e$ = 2.60x10-2 Torr.
Go back to Figure 9.20 of PDG00 to get an improved estimate of about 1150 $^o$C.

**6.2 Chemical vapor deposition: transport and reaction regimes**

a) At high temperature of 1473 $^o$K, $v = h_G(C_T/N)Y = 0.5\ (1/10{,}000)(1/760) = 6.58\text{x}10^{-8}$ cm/s.
At low temperature of 873 $^o$K, $k_S = 4\text{x}10^6 e^{-1.5/(8.617\text{x}10\text{-}5 \text{ x } 873)}$ and $v = k_S(C_T/N)Y = 8.76\text{x}10^{-3}$ x (1/10,000)(1/760) = $1.15\text{x}10^{-9}$ The crossing temperature occurs when $k_S = h_G$ and is $T = E_A/(15.89 \text{ x } k)$ = 1095 $^o$K.
b) The high pressure rate is 100 times higher to $6.58\text{x}10^{-6}$ cm/s and the crossing temperture moves to $T = E_A/(11.29 \text{ x } k)$ = 1095 $^o$K. Sketch is similar to Figure 9-13 pp. 526 PDG.

**6.3 Physical vapor deposition**

| | **10** | **20** | **30** | **50** |
|---|---|---|---|---|
| $F_{BOTTOM}$ | **0.93** | **0.35** | **0.20** | **0.07** |
| $F_{SIDEWALL}$ | **0.07** | **0.07** | **0.05** | **0.035** |
| $F_{ENCROCH}$ | **0.06** | **0.12** | **0.21** | **0.28** |
| $F_{PINCH}$ | **>3** | **2.7** | **2.1** | **1.2** |

- Bottom fractional coverage = maximum height of the material on the bottom of the trench normalized to the deposition thickness for large flat areas.
- Side fractional coverage = thickness at the midpoint of the side of the trench normalized to the deposition thickness for large flat areas.
- Relative lateral encroachment rate = incremental lateral change of the initial profile normalized to the incremental deposition thickness for large flat areas.
- Void pinch ratio = deposition thickness at which the trench opening becomes 50% of its initial width divided by the trench width.