3.155J/6.152J
Microelectronic Processing Technology
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Problem Set 1 Solutions **Out Feb. 9, 2005** **Due Feb.16, 2005**

Gas kinetics, vacuum technology

Reading Assignment: Kinetics, Vac. Tech.: Campbell, 10.1 – 1.4 (or Ohring Ch. 2) .
Useful constants: $k_B = 1.38\times10^{-23}$ **J/Kelvin,** **1 atm = 10^5 Pa or N/m^2,**
N_A **= 1/mass proton in grams =** 6.02×10^{23} **(at/gram-mole),**
$R = N_A \times k_B =$ **8.31 J/K-mole,**

1. Consider a vacuum system at room temperature that has been pumped down to a pressure of 10^{-5} Torr and backfilled with Ar to a pressure of 5 mT. (Make an intelligent estimate of the diameter of an Ar atom.)
a) Calculate the mean free path, λ, of the Ar atoms at this pressure.
b) Calculate the volume density of Ar atoms.
c) Calculate the flux of Ar atoms, J (molecules/(cm^2-s)) impinging on a surface in the chamber.
d) Calculate the average speed of an Ar atom in this case.

2. Answer Question 1, a – c) for air (N_2) at 5 mT using the figure on page 8 of Lec. 3.

Read: Plummer Secs. 9.1, 9.21 - 9.22. Campbell, Ch. 10, Secs. 1 - 3, all of Ch. 13.

CVD

3. Assume chemical equilibrium is established in a CVD reactor according to the equation:

$$SiH_4\,(g) \leftrightarrow SiH_2\,(g) + H_2\,(g)$$

The temperature is maintained at 700° C and the pressure at 100 mT. If the equilibrium constant for the reaction is $K(T) = 2 \times 10^9$ (Torr) exp[-1.8 eV/(k_BT)], find the partial pressure of each gas assuming $p(H_2) \approx p(Si\,H_2)$.

4. Assume a CVD process based on the reaction: $2AB(g) \leftrightarrow 2A(s) + B_2(g)$.
   a) Sketch and briefly describe the atomic-scale steps that control the reaction.
   b) How would you distinguish between i) the reaction-limited and ii) a transport-limited cases?
   c) Sketch the variation of the log of the CVD growth rate as functions of the square root of the gas flow velocity and as a function of $1/T$.
   d) If you wanted to increase the growth rate of a transport-limited CVD process, what processing variables would be most effective? (List them in decreasing order of efficacy.)