3.155J/6.152J
Microelectronic Processing Technology
Fall Term, 2005

Bob O'Handley

Martin Schmidt

Problem Set 4 Out Oct. 5, 2005 Due Oct.17, 2005

Gas kinetics, vacuum technology

Reading Assignment: Class notes.

Optional: 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 being prepared for a reactive deposition at room temperature; the chamber has been pumped down to a pressure of 10^{-6} Torr and backfilled with O_2 to a pressure of 5 mT. (Make an intelligent estimate of the diameter of an O_2 molecule.)
   a) Calculate the mean free path, λ, of the O_2 molecules at this pressure.
   b) Calculate the volume density of O_2 molecules.
   c) Calculate the flux of O_2 molecules, J (molecules/(cm^2-s)) impinging on a surface in the chamber.
   d) Calculate the average speed of an O_2 molecule in this case.

2. Kevin and Karen each have their own uhv deposition chambers but they share a bank of cryo-pumps that sits between their chambers and are used for roughing out their chambers without the oil contamination that can come from a mechanical pump. These cryo-pumps are permanently connected to the two chambers with 1-inch inner diameter stainless-steel piping of length 4 feet to each chamber. (Each chamber has its own valve for these pumps so Kevin and Karen can operate on their own schedules.) Kevin's ion pump breaks down and he asks Karen if he can run an 8-foot length of stainless pipe, 1-inch ID, to a blank flange on her chamber till his ion pump is refurbished. The next time Karen pumps down with Kevin's chamber connected to hers, it takes a little longer but her chamber eventually gets down to 10^{-9} Torr. Even after a week Kevin's chamber is still in the 10^{-5} range Torr. Why? (One or two sentences should do; maybe an equation.)

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 pressure is maintained at 10 mT and the temperature at 500° C. If the equilibrium constant for the reaction is $K(T) = 2 \times 10^9$ (Torr) $\exp[-1.8\text{ eV}/(k_B T)]$, 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 CVD growth rate as functions of the square root of the gas flow velocity and sketch the variation of the log of the CVD growth rate 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.)