

ENSC 495/851 Problem Workshop 3 Mar. 25, 2015

3. The sputter vacuum system is not pumping down to the needed pressure for aluminum deposition. You find that air from the room leaks into the vacuum chamber at the rate of 0.800cm^3 per second (volume at atmospheric pressure). Both the roughing and diffusion pump have a maximum pumping speed in the system of 1200 liters per second.

(a) Find the limit of the achievable vacuum (3 marks)

(b) In which pumping is the limit going to occur: in the roughing or diffusion pumping region? (1 mark)

Solution:

(a) The pumping flow rate Q_{pump} (Litre-atm/sec) is given by

$$Q_{\text{pump}} = PS$$

Where P is the pressure (in atm) and S the pumping speed in (in Litre/sec) = 1200 liters/sec

Pumping occurs until the pressure where the leakage Q_{leak} into the chamber equals the pumping flow rate

$$Q_{\text{leak}} = 0.800 \text{ cm}^3\text{-atm/sec} = 0.800/1000 \text{ litre-atm/sec}$$

Thus the limiting pressure is

$$P_{\text{limit}} = \frac{Q_{\text{leak}}}{S_{\text{pump}}} = \frac{0.800}{1000 * 1200} = 6.667\text{E-}07 \text{ atm}$$

(2 marks)

Converting to torr: $P_{\text{limit}} = 6.667\text{E-}07 * 760 = 5.067\text{E-}04 \text{ torr}$

(1 mark)

(b) Both pumps have the same limiting pumping rate S. Since the limit of the roughing pump is typically 1 mTorr, the $P_{\text{limit}} = 5.067\text{E-}04 \text{ torr}$ is less than the limit, the pumping region is a diffusion pump. (1 mark)

7. Using the given activation energies for each process, estimate the relative increase in reaction rate for: (a) Silicon dioxide as temperature rises from 434 to 514 °C with $E_a = 0.4$ eV (b) Silicon nitride from 658 to 904 °C with $E_a = 1.8$ eV. (c) Polysilicon from 531 to 747 °C with $E_a = 1.7$ eV; (d) silicon epitaxy (using silane) from 1048 to 1159 °C with $E_a = 1.65$ eV.

By Arrhenius equation, the ratio of the rates is given by:

$$\exp \left\{ \left(\frac{E_a}{k} \right) \left(\frac{1}{T_1} - \frac{1}{T_2} \right) \right\}$$

Hence: (with $k = 8.67 \times 10^{-5} \text{ eV K}^{-1}$)

	(a) (2 marks)	(b) (2 marks)	(c) (2 marks)	(d) (2 marks)
E_a (eV)	0.4	1.8	1.7	1.65
Ratio of rates	1.94	108.94	183.10	3.08
% increase	94	10794	18210	208