

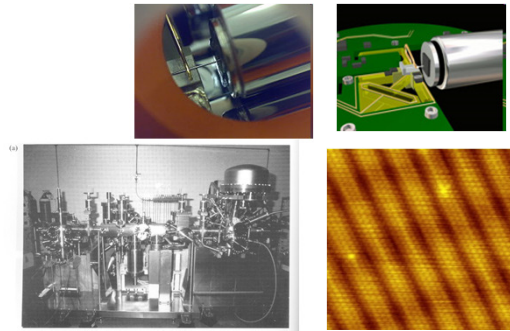
Tecnologia de Vácuo

Manômetros
Fluxômetros
Escoamento

Prof. José Humberto Dias da Silva
Ciência e Tecnologia de Filmes Finos
POSMAT – Unesp/Bauru - 2011

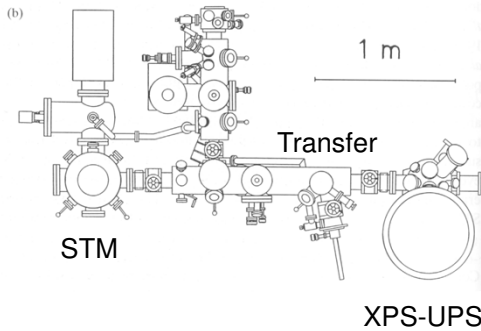
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STM – microscópio de tunelamento



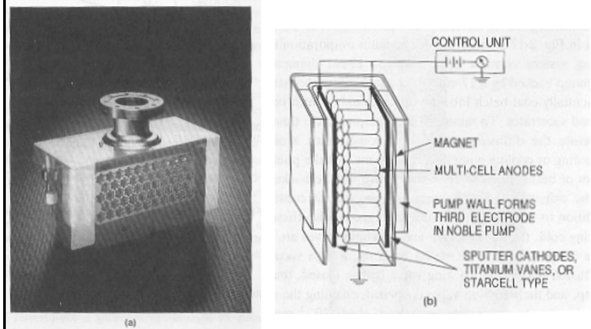
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Preparação



Weisendanger

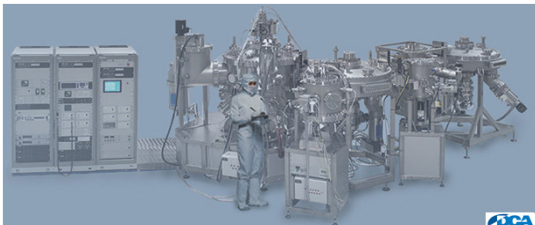
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• Bombas iônicas e de sublimação

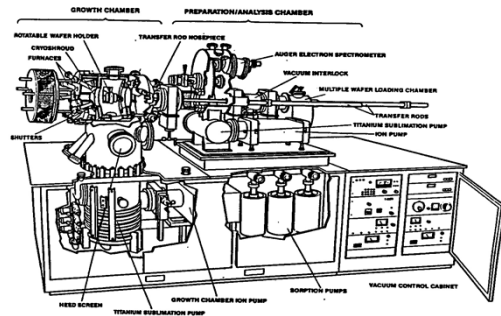
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Sistema de MBE

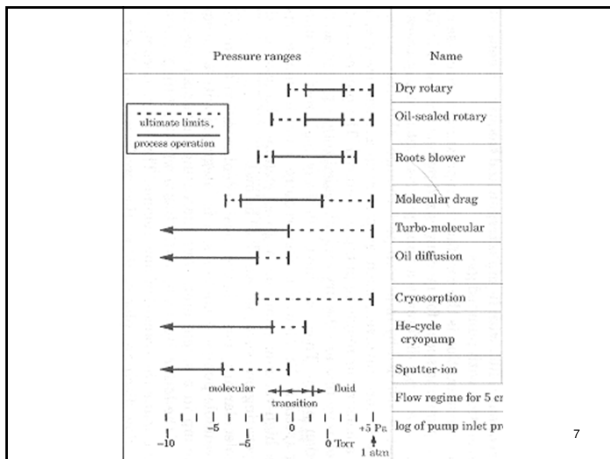


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Sistema de MBE



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Vácuo: ponto importante

- As bombas utilizadas dependem da pressão final e do fluxo de gases a ser bombeado.

Temas de hoje:

- Medidores de pressão
- Analisadores de gases
- Regimes de escoamento
- Medidores de Fluxo
- Vazão e velocidade de bombeamento
- Exercícios – Cap. 3

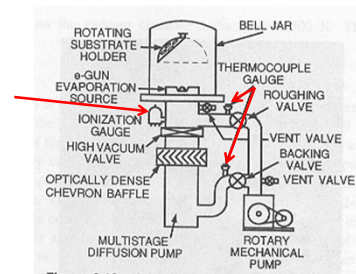
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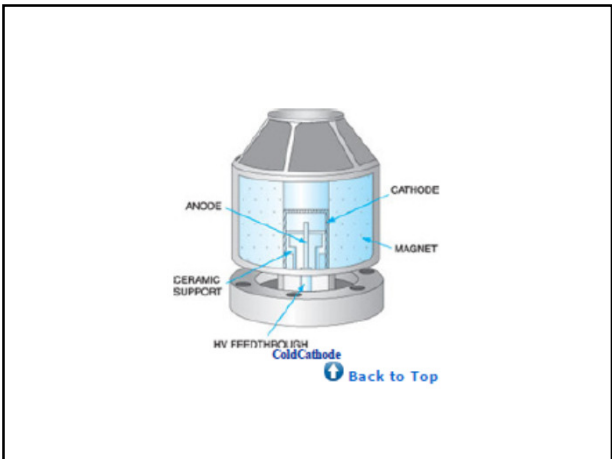
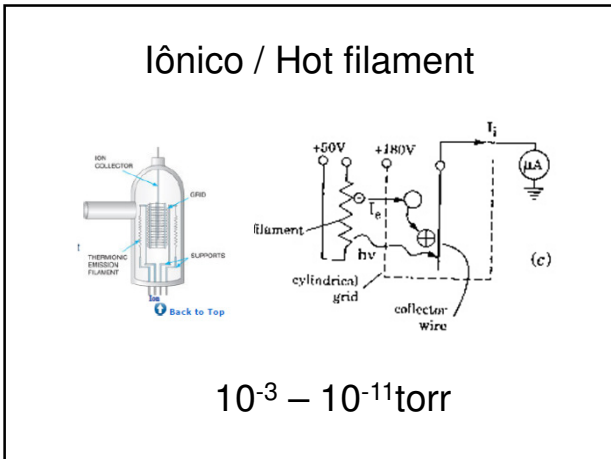
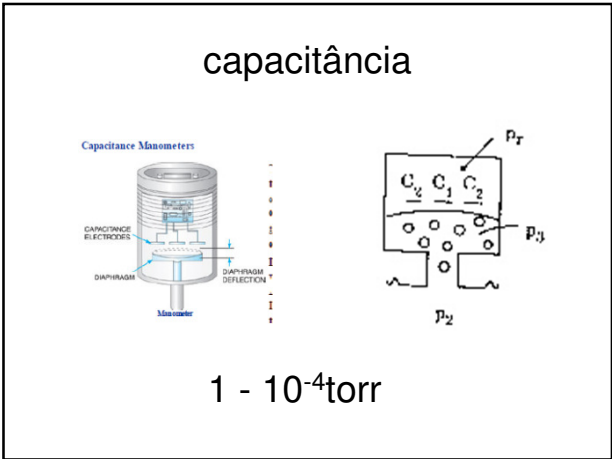
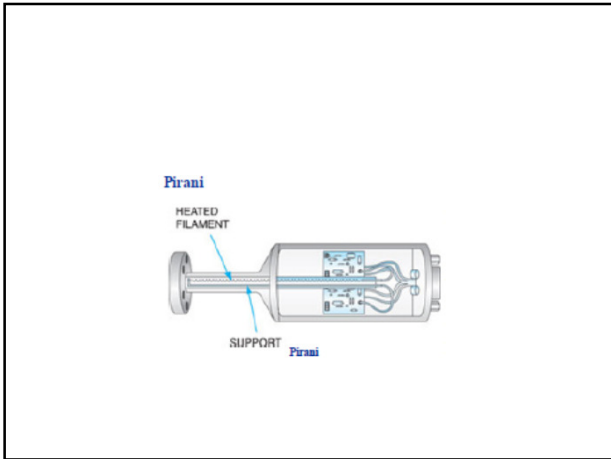
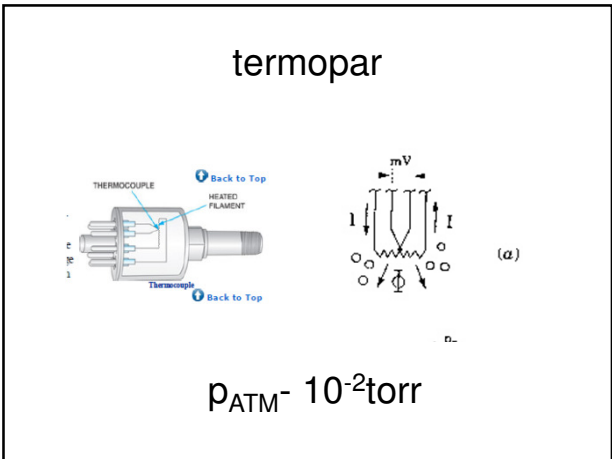
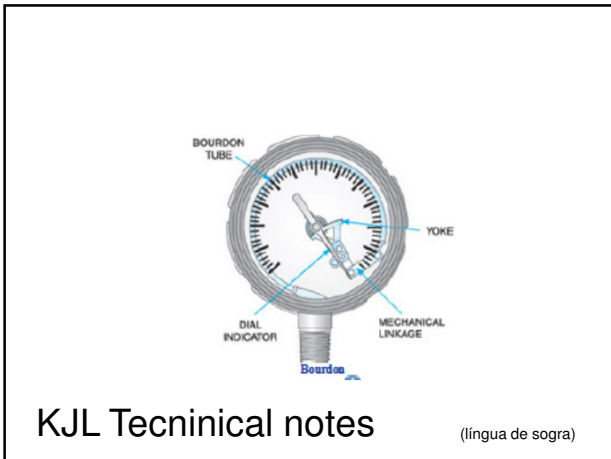
Antes:

- Visita ao Lab. de Filmes Semicondutores

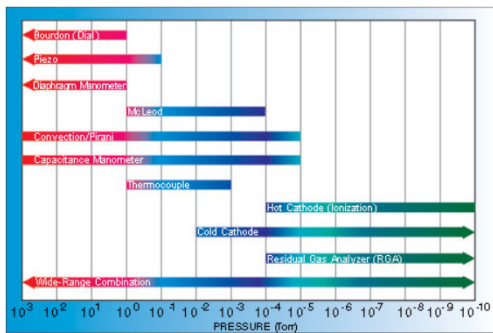
- Medidores de pressão

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Range – medidores de pressão



Medidores de Pressão

Conclusão:

* os medidores de pressão (vácuo) têm suas escalas típicas.

- Medidores de pressão
- Analisadores de gases
- Regimes de escoamento
- Medidores de Fluxo
- Exercícios – Cap. 3

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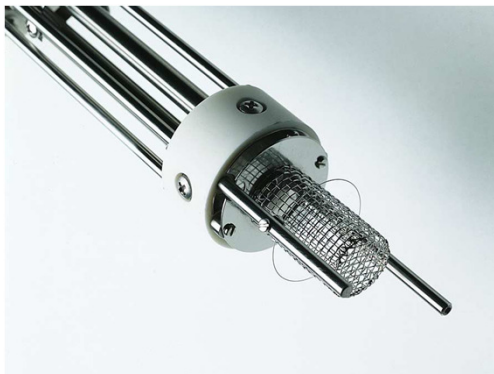
Analizador de gases residuais

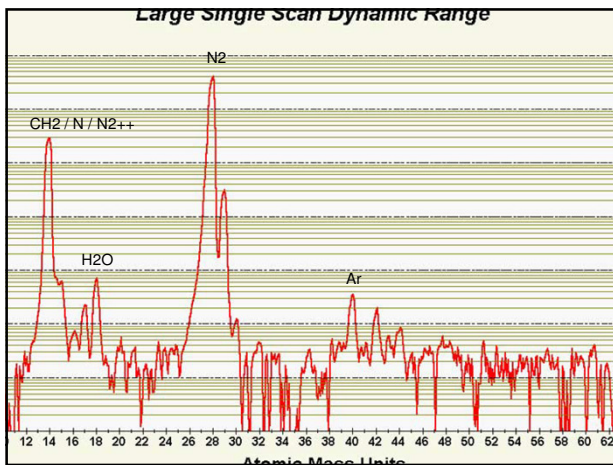


- 100, 200 and 300 amu systems
- Better than 1 amu resolution
- 6 decades of dynamic range
- 5×10^{-14} Torr detection limit
- RGA Windows & LabVIEW software
- Field-replaceable electron multiplier and filament
- RS-232 interface

$p_{res} \sim 10^{-2} - 10^{-12}$ torr

Analizador de gases residuais





- Medidores de pressão
- Analisadores de gases
- Regimes de escoamento
- Medidores de Fluxo
- Exercícios – Cap. 3

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Reator CVD complexo (comercial)

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Fluxo de gás / Inomogeneidades

322 Chemical Vapor Deposition

Figure 7.12 Typical free-convection roll cells: (a) horizontal rectangular-tube reactor (view along axis) with two alternate sidewall conditions, insulated (left) and cooled (right); (b) downflow axisymmetric reactor, showing two alternate flow patterns. In (b), the recirculating pattern (right) is to be avoided.

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Distribuição de velocidades nas proximidades do susceptor (porta substratos).

Figure 7.8 Velocity boundary layer of width δ_v forms at the susceptor leading edge in a tube reactor.

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Linhas de fluxo de gás / simetria axial

Figure 7.10 Axisymmetric flow pattern over a rotating disc. (Source: Reprinted from Ref. 7 by permission, © 1968 by McGraw-Hill Book Co.)

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Regimes de Escoamento

$$K_n = l/L$$

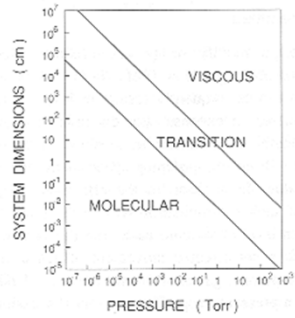
l = livre caminho médio

L = tamanho do sistema

Número de Knudsen:

- $Kn > 1$ – alto vácuo, colisões molécula-paredes (**molecular**)
- $Kn \ll 0,01$ – fluxo de fluido, colisões molécula-molécula (**fluido / viscoso**)
- $0.01 \ll Kn < 1$ – regime intermediário

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Regimes de fluxo de gás dominantes em função das dimensões do sistema e pressão

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- Medidores de pressão
- Analisadores de gases
- Regimes de escoamento
- Controladores de Fluxo
- Exercícios – Cap. 3

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fluxo ~ 0.1 – 200 sccm

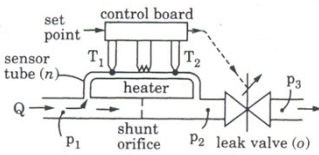
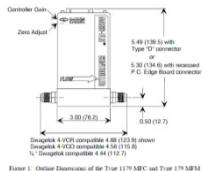


Figure 7.3 Thermal-mass flow controller schematic.

fluxo ~ 0.1 – 200 sccm

- Medidores de pressão
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Vazão

$$Q = C \cdot \Delta p$$

Q – gas throughput (fluxo de massa, vazão)

Unidades: pressão x volume por segundo [Pa.l/s], [Torr.l/s]

C – condutância [l/s]

Velocidade de Bombeamento

$$Q_o = C_o p_o$$

C_o – velocidade de bombeamento [l/s]

Q_o – vazão na bomba (fluxo de massa retirado do sistema).

P_o – pressão na boca da bomba

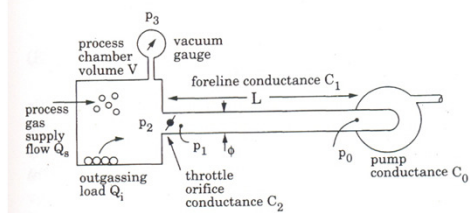


Figure 3.3 Geometry for gas throughput calculations.

Velocidade de Bombeamento

$$Q_o = C_o p_o$$

C_o – velocidade de bombeamento [l/s]

Q_s – supplied throughput (fluxo de massa injetado no sistema).

Q_i – outgassing from the chamber (fluxo degasagem).

Esquema - sistemas de vácuo

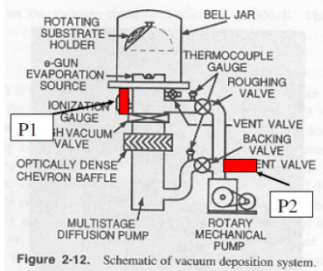
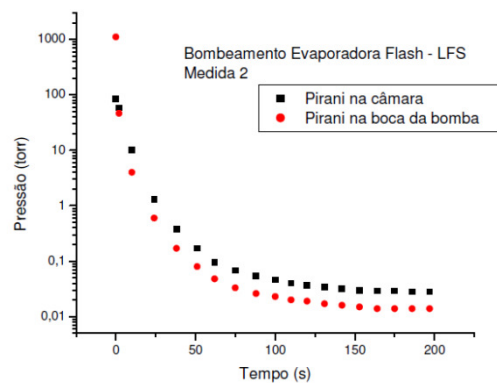


Figure 2-12. Schematic of vacuum deposition system.



entrada + geração = saída + acumulação
(Equação da continuidade)

sistema fechado ↓ ↓ quant perdida
 $0 = C_o p_2 + V \frac{dp_2}{dt}$
 ↑ quant bombeada

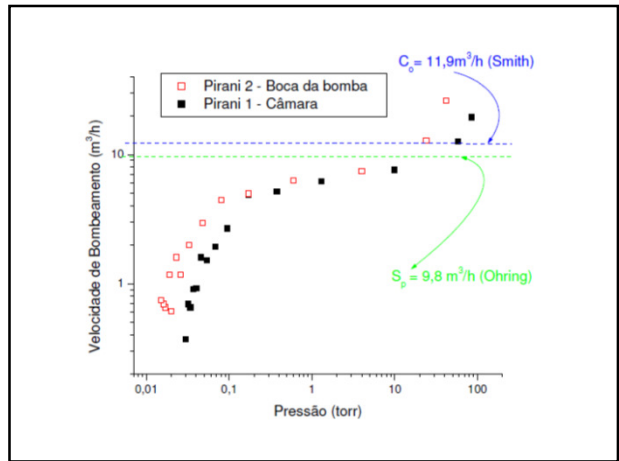
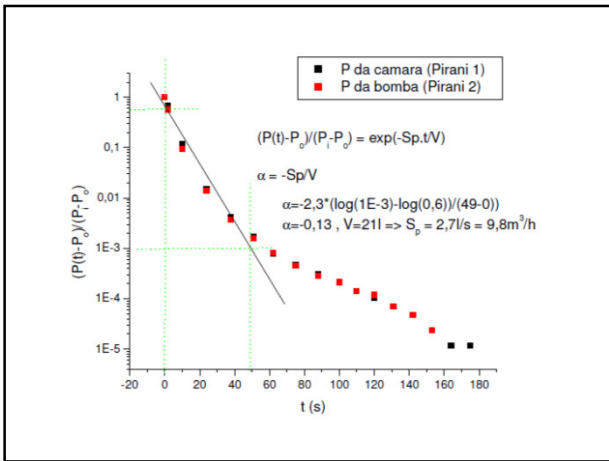
$$-\left(\frac{C_o}{V}\right) dt = \frac{dp_2}{p_2}$$

(Equação Característica do Bombeamento)

$$p_2 = p_{2o} e^{-\left(\frac{C_o}{V}\right)t} = p_{2o} e^{-\alpha t}$$

$$\alpha = C_o / V$$

C_o – velocidade de bombeamento
 V – volume do sistema



1/8 ROTARY VANE PUMP
 $7 \text{ m}^3\text{h}^{-1}, 5,7 \text{ ft}^3\text{min}^{-1}, 162,7 \text{ l min}^{-1}$

TECHNICAL DATA

placement	$9,7 \text{ m}^3\text{h}^{-1} / 5,7 \text{ ft}^3\text{min}^{-1}$
60 Hz operation	$11,7 \text{ m}^3\text{h}^{-1} / 6,9 \text{ ft}^3\text{min}^{-1}$
rod (Pneurop 6602)	
60 Hz operation	$8,5 \text{ m}^3\text{h}^{-1} / 5 \text{ ft}^3\text{min}^{-1}$
60 Hz operation	$10 \text{ m}^3\text{h}^{-1} / 5,9 \text{ ft}^3\text{min}^{-1}$

GAS BALLAST	ULTIMATE VACUUM (TOTAL PRESSURE)	
	HIGH VACUUM MODE	HIGH THROUGHPUT MODE
speed	$2 \times 10^{-3} \text{ mbar}$	$3 \times 10^{-2} \text{ mbar}$
	$1,5 \times 10^{-3} \text{ Torr}$	$2,3 \times 10^{-2} \text{ Torr}$
flow, l	$3 \times 10^{-2} \text{ mbar}$	$4 \times 10^{-2} \text{ mbar}$

O fluxo do gás bombeado (nitrogênio ou ar) para fora da câmara ocorre em regime molecular ou fluido ?

Nossas pressões => p maior 760 torr , menor 10⁻³ torr

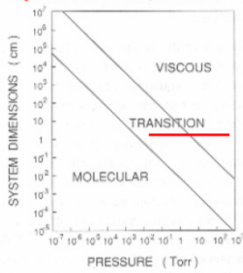


Figure 2-3. Dominant gas flow regimes as a function of system dimensions and pressure.

(obs: diâmetro do tubo ~ 2cm)

impurezas

$$p_i = Q_i / C_o$$

$$\frac{p_i}{p_s} = \frac{Q_i}{Q_s + Q_i} \approx \frac{Q_i}{Q_s}$$

i – impurity outgassing

s – supply gas

Comentários Finais e Sumário

- Escolher bomba de acordo com pressão final e quantidade de gás bombeado.
- Escolher medidor de acordo com pressão final.
- Controlador de fluxo: ferramenta importante para processos CVD
- Analisador de gases residuais: consigo saber quais os contaminantes do sistema.

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Exercícios Cap. 3

3.4
3.6
3.8
3.10
3.12

- 3.4 A process chamber of 1 m² surface area is outgassing at a rate of 10⁻³ mo/cm²·s. For a process-gas flow of 200 sccm and a total pressure of 100 Pa, what is the partial pressure of the outgassing impurities?
- 3.5 List the advantages of N₂ purging of pumping systems.
- 3.6 What are the pump choices for a process operating at 10⁻² Pa, and what are the relative advantages and disadvantages of each?
- 3.7 A pump foreline 5 cm in diameter and 300 cm long is being purged with Ar. (a) How many sccm of Ar flow are required to attenuate the pump-oil partial pressure by 10¹⁰ over the length of the tube? (b) What will be the total pressure, p, at the upstream end if the pumping speed is such that p at the downstream end is 50 Pa?
- 3.8 Suppose that the inside surface of an Al vacuum chamber is coated with 100 nm of poorly formed anodic oxide having 20 percent porosity consisting of 2-nm-diameter cylindrical pores. (a) What is the ratio of the total internal surface area of the pores to the macroscopic area of the Al surface? (b) If two monolayers of water are adsorbed on all of the internal surface area, how many sec are adsorbed per m² of macroscopic area?
- 3.10 Water diffusing through an elastomer O-ring seal from atmosphere at a rate of 0.01 sccm is the principal background gas in a particular vacuum chamber being pumped at 1000 l/s. What is the partial pressure, in Pa, of water in the chamber?
- 3.11 An ion gauge which indicates pressures p_i is being calibrated against a capacitance diaphragm gauge which indicates pressures p_s and which has a zero offset of p₀. The following three data points (p_s, p_i) are taken, in units of Pa: (0.12, 0.04), (0.10, 0.03), and (0.06, 0.01). (a) What is p₀? (b) What is the ion gauge calibration factor f = p_i/p_s?
- 3.12 List the factors affecting the level of water background in a vacuum chamber.

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