INSTITUTO
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DE AERONÁUTICA

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MT-203
Ciência e Tecnologia de Filmes Finos

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Aula de Exercícios

- Cap 2: 1, 3, 5, 6, 9
- Cap 3: 3, 4, 5, 9,
- Cap 4: 7, 8, 11, 13
- Cap 5: 1, 2, 3, 4, 6, 7, 8, 13
- Cap 6: 1, 3, 14

Cap 2

2.5

2.5 An Al film is being deposited at 5 μm/h in a background of 1×10^{-7} torr of O_2. What will be the maximum atomic percent oxygen in the deposit?

$$J_r\left(\frac{mc}{cm^2\cdot s}\right) = 1.67\times10^{16}\,\frac{\frac{dh}{dt}\,(\mu m/h)\,\rho_m\left(g/cm^3\right)}{M\,(g/mol)}$$

$$J_i\left(\frac{mc}{m^2\cdot s}\right) = \frac{N_A p}{\sqrt{2\pi MRT}}$$

Cap 2

2.9 Single-crystal Si is being deposited at 1.0 μm/h onto one face of a 4 inch diameter heated substrate in a CVD process by pyrolysis (thermal decomposition) of the reactant dichlorosilane (SiH_2Cl_2) flowing at 10 sccm. What fraction of the reactant is being utilized in the deposition?

$$J_r\left(\frac{mc}{cm^2 \cdot s}\right) = 1.67\times10^{16}\ \frac{\frac{dh}{dt}(\mu m/h)\,\rho_m\left(g/cm^3\right)}{M\,(g/mol)}$$

2.3 Show that 1 sccm = 4.48×10^{17} mc/s.

Cap 3

3.4 A process chamber of 1 m^2 surface area is outgassing at a rate of 10^{13} $mc/cm^2 \cdot s$. For a process-gas flow of 200 sccm and a total pressure of 100 Pa, what is the partial pressure of the outgassing impurities?

$$J_i\left(\frac{mc}{m^2 \cdot s}\right) = \frac{N_A p}{\sqrt{2\pi MRT}}$$

2.3 Show that 1 sccm = 4.48×10^{17} mc/s.

Cap 3

3.9 **How many seconds will it take for a 1 cm^3 virtual leak to evacuate from 10^2 to 10^{-6} Pa through a 10^{-2} cm-diameter, 1 cm-long capillary?**

$$Kn = l/L$$

$$C_m = 12.3\phi^3/L \quad l/s$$

$$C_f = 1.41\phi^4\bar{p}/L \quad l/s$$

- L = menor dimensão interna do sistema (largura, distância entre eletrodos, etc...)
- Kn > 1 → sistema está em **regime molecular**
- Kn < 0,01 → sistema está em **regime fluido** (viscoso)
- 0,01 ≤ Kn ≤ 1 → sistema está em **regime de transição** (intermediário)

ϕ = tube diameter, cm
L = tube length, cm; L >> ϕ

Cap 3

3.9 **How many seconds will it take for a $1\ cm^3$ virtual leak to evacuate from 10^2 to 10^{-6} Pa through a 10^{-2} cm-diameter, 1 cm-long capillary?**

$$Q = C\,\Delta p$$

$$-\frac{dN}{dt} = C\,p \quad (p_0 = 0)$$

$$-\frac{V}{RT}\frac{dp}{dt} = \frac{12{,}3\,\phi^3}{L}\,p$$

$$\Rightarrow \Delta t = \frac{V}{RT}\frac{L}{12{,}3\,\phi^3}\int_{p_f}^{p_i}\frac{dp}{p}$$

$$\Delta t = \frac{V}{RT}\frac{L}{12{,}3\,\phi^3}\ln\left[\frac{p_i}{p_f}\right]$$

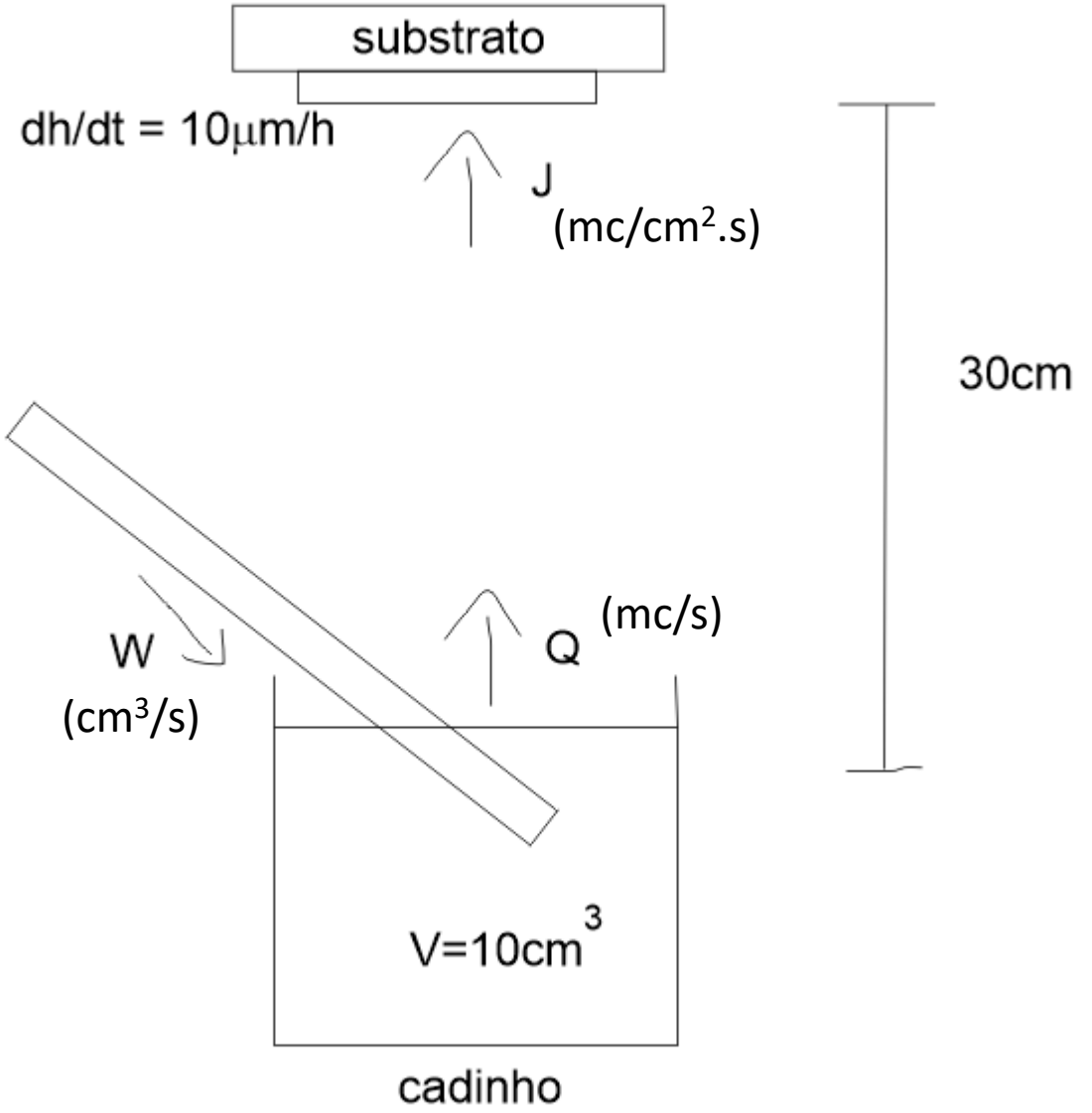
Cap 4

4.7 An alloy is being deposited by wire feed into a crucible melt having $V = 10\ cm^3$. The deposition rate on a substrate 30 cm directly above the crucible is 10 μm/h. (a) Assuming cosine-law effusion, what is the volume feed rate of wire, W, required to hold V constant after the melt reaches steady-state composition? (b) How many hours will it take for the melt to drift 90 percent of the way from initial to steady-state composition, assuming that $\tau = V/W$?

Cap 4

4.7 (a)

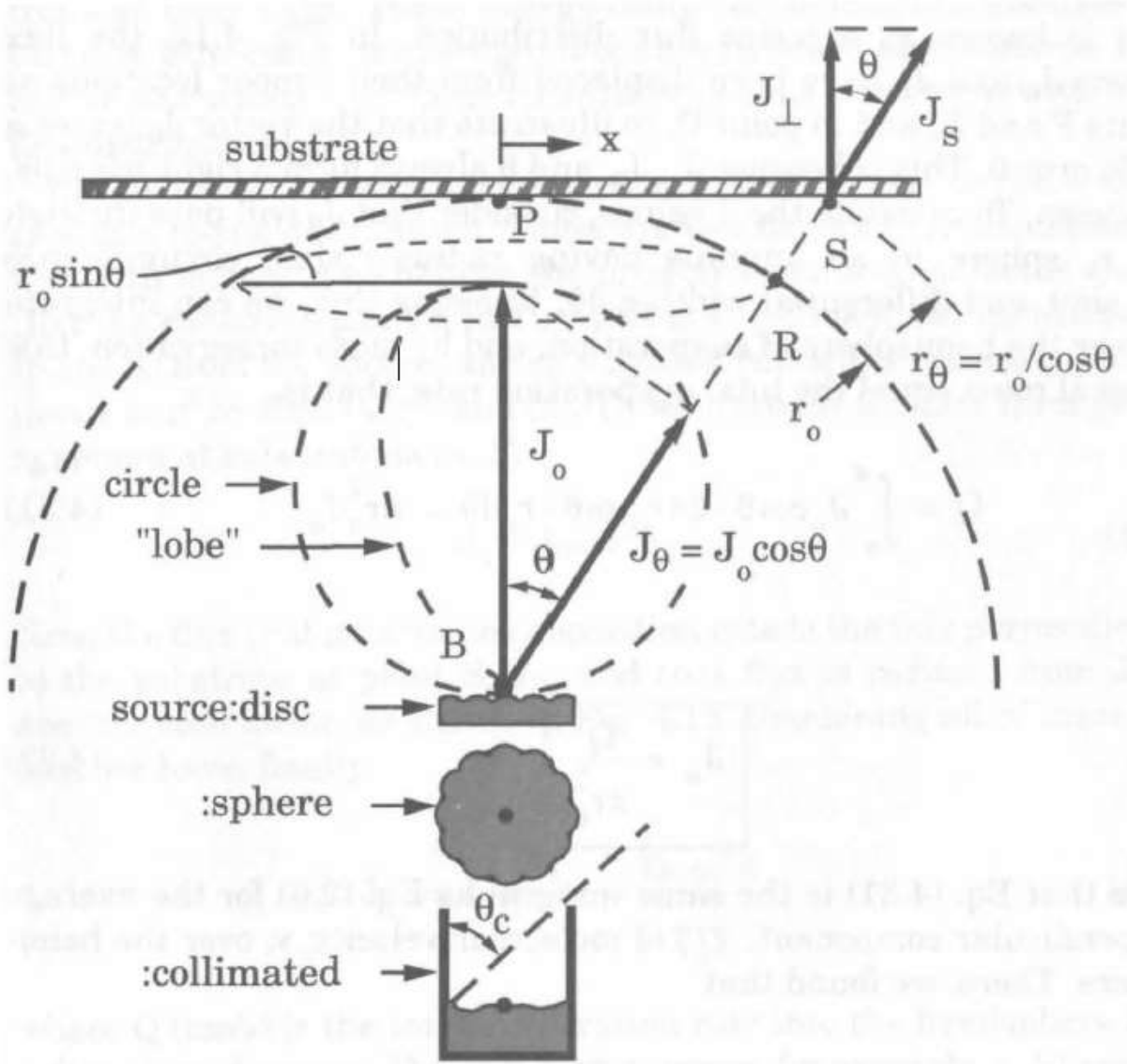
$$J_r\left(\frac{mc}{cm^2 \cdot s}\right) = 1.67\times10^{16}\ \frac{\frac{dh}{dt}(\mu m/h)\,\rho_m\left(g/cm^3\right)}{M\,(g/mol)}$$



Cap 4

4.7 (a)

$$J_o = \frac{Q}{\pi r_o^2}$$



Cap 4

4.7 (b) t = ?, para $\xi = 0.9$

$$\xi = \frac{x_s - x}{x_s - y} = \exp\left(\frac{-t}{V x_s / W y}\right) = e^{-t/\tau} \qquad (4.25)$$

Cap 4

4.7 (b) t = ?, para $\xi = 0.9$

$$\xi = \qquad = \exp\left(\frac{-t}{V \quad / W}\right) \tag{4.25}$$

Cap 4

4.11

4.11 Show by integration that, for a cosine distribution of evaporant, the evaporant flux perpendicular to the source plane is twice the average flux over the hemisphere.

$$J_s = J_\theta \cos^2\theta$$

$$\frac{1}{2\pi}\int_0^{2\pi} \mathrm{Cos}[\theta]\,\hat{}\,2\,d\theta$$

Exercícios (aula 4)

1) Sabendo que um filme de 500nm de silício cristalino é crescido em 2horas. Qual o tempo médio para formação de 1 camada atômica (monocamada) de Si no filme em crescimento? Suponha crescimento bidimensional no plano (111).

Dados:

ρ = 2.330 kg/m^3 = 2,33 g/cm^3

M = 28,1 uma = 28,1 g/mol

a (parâmetro de rede) = 0,543 nm

Difusão Superficial

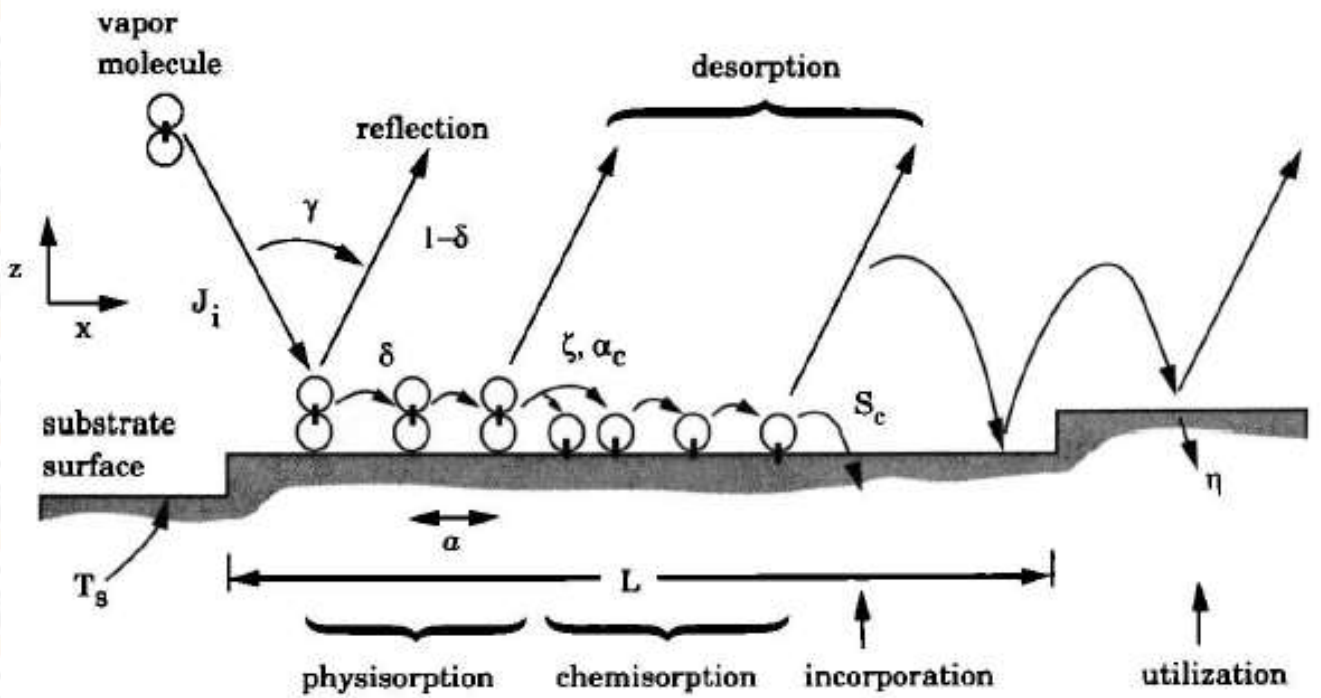
Mas enquanto o precursor passeia na superfície, o filme está crescendo:

- Para um filme de 500 nm de Si (100) – estrutura diamante - crescido em 2horas:
  - dh/dt = 0,25μm/h = 250nm/3600s = 0,0694 nm/s
  - Parâmetro de rede do Si = 0,543 nm
  - São 4 camadas atômicas (100) por cela
  - Espessura da camada atômica = 0,543/4 = 0,136 nm
  - t (monocamada (100)) = 1,95 s
  - Outra forma de calcular:

$$J_r\left(\frac{mc}{cm^2 \cdot s}\right) = 1.67\times10^{16}\ \frac{\frac{dh}{dt}(\mu m/h)\,\rho_m\left(g/cm^3\right)}{M\,(g/mol)}$$

Cap 5

5.1 A molecule has a condensation coefficient of $\alpha_c = 0.2$ on a depositing film of its own solid phase. For this molecule, what are the minimum and maximum values of the thermal accommodation coefficient, γ; trapping probability, δ; sticking coefficient, S_c; and utilization factor, η?



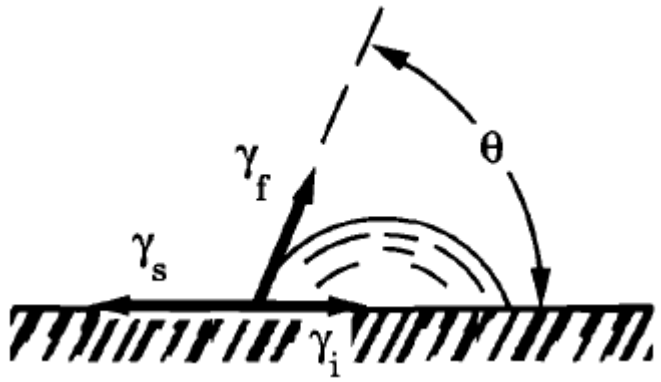
Cap 5

5.3 For condensation onto nonwetting substrates at 300 K using a 10^{-4} Pa overpressure, what are the classical critical-nucleus radii for the following metals, neglecting substrate contact area and γ_f anisotropy? (a) Au, with $\gamma_f = 1400$ ergs/cm^2 (dynes/cm); (b) Pb, with $\gamma_f = 560$ ergs/cm^2.

$$r^* = \frac{2\gamma_f}{\left(\frac{RT}{V_{mc}}\right)\ln\left(\frac{p}{p_v}\right)}$$

Cap 5

5.4 Derive Young's equation [Eq. (5.45)] using surface-energy minimization.

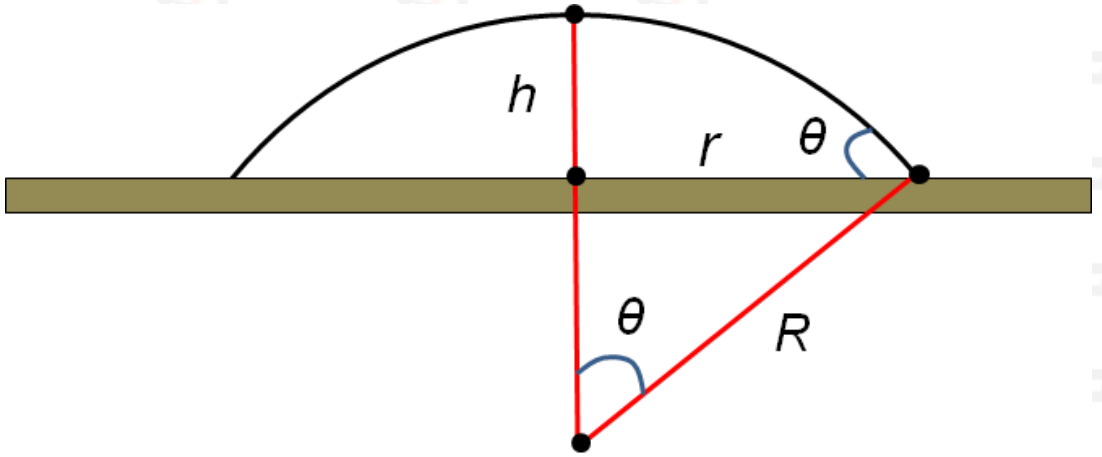


$$\gamma_i + \gamma_f \cos\theta = \gamma_s$$

Cap 5

5.4

$$A = 2\pi Rh \text{ or } A = 2\pi R^2(1-\cos\theta).$$



V = constante

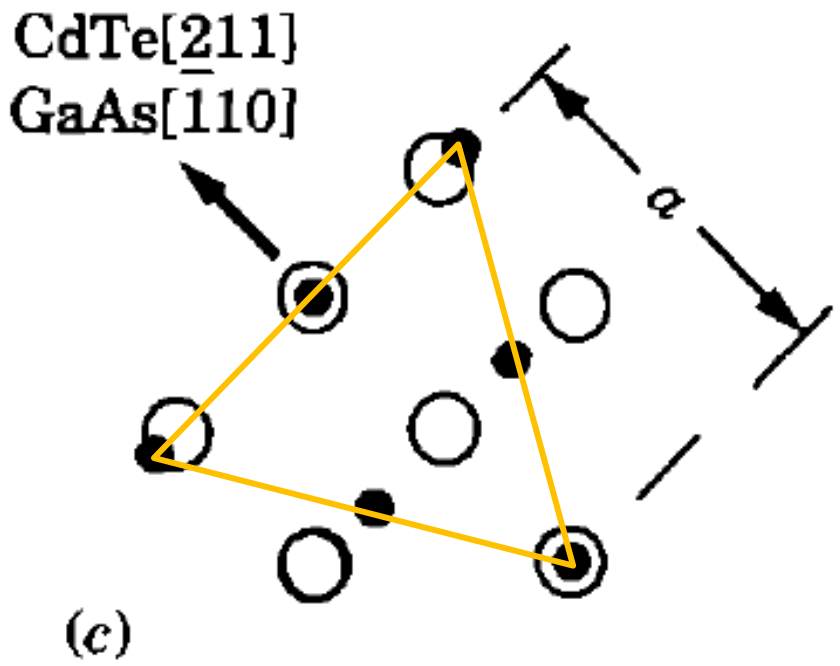
$$V = \frac{\pi h}{6}(3r^2 + h^2) \qquad V = \frac{\pi R^3}{3}(1-\cos\theta)^2(2+\cos\theta) \qquad \frac{d\theta}{dR} = -\frac{(1-\cos\theta)(2+\cos\theta)}{R\sin\theta(1+\cos\theta)}$$

$$E = \pi r^2(\gamma_i - \gamma_s) + 2\pi Rh\cdot\gamma_f = \pi(R\sin\theta)^2(\gamma_i - \gamma_s) + 2\pi R^2(1-\cos\theta)\gamma_f$$

dE/dR = 0 (minimização da energia)

Cap 6

6.1 For epitaxy of CdTe(111) on GaAs(001) as shown in Fig. 6.1c: (a) show by a geometrical construction similar to Fig. 5.7 that the [211] direction of CdTe does indeed lie in the (111) plane. (b) Using the a_o data of Fig. 6.3, calculate the atomic spacing a shown in Fig. 6.1c for GaAs and for CdTe.



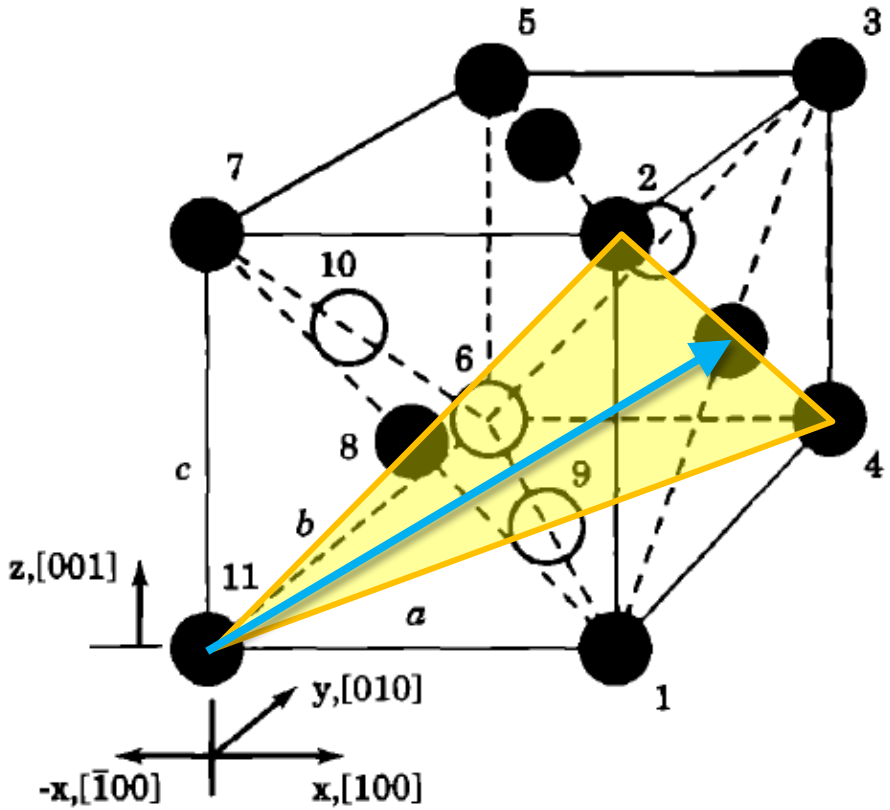


Figure 5.7 Geometry of a face-centered cubic crystal.

Cap 6

6.1 For epitaxy of CdTe(111) on GaAs(001) as shown in Fig. 6.1c: (a) show by a geometrical construction similar to Fig. 5.7 that the [211] direction of CdTe does indeed lie in the (111) plane. (b) Using the a_o data of Fig. 6.3, calculate the atomic spacing a shown in Fig. 6.1c for GaAs and for CdTe.