

A Técnica de MBE

POSMAT
Prof. José Humberto Dias da Silva

Perguntas da aula sobre Epitaxia:

Como produzir interfaces e camadas finas, com alta pureza e controle?

2

Como crescer tantas camadas e com tal precisão ?

3

Epitaxia por Feixe Molecular (MBE)

Molecular Beam Epitaxy

MBE

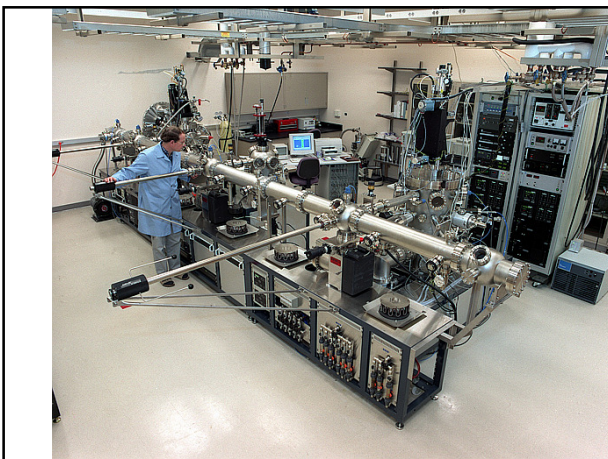
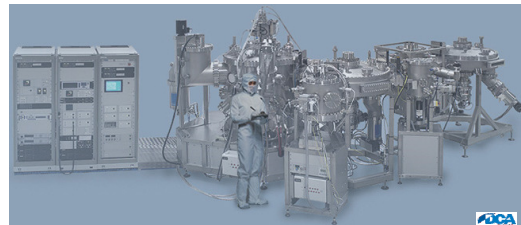
Características

Caracterização "in-situ":
REED (difração de elétrons)
XPS-UPS
Pressão residual $< 10^{-10}$ torr
Alto controle de $T_{\text{substrato}}$
Excelente contr. das células de efusão
Transferência de substr. em vácuo

Propaganda comercial
de MBE =>



Produção de MQW-LEDs e LASERS: várias etapas – em vácuo



MBE

- Controle
- SIMPLICIDADE ?!?!??

Sistema de MBE

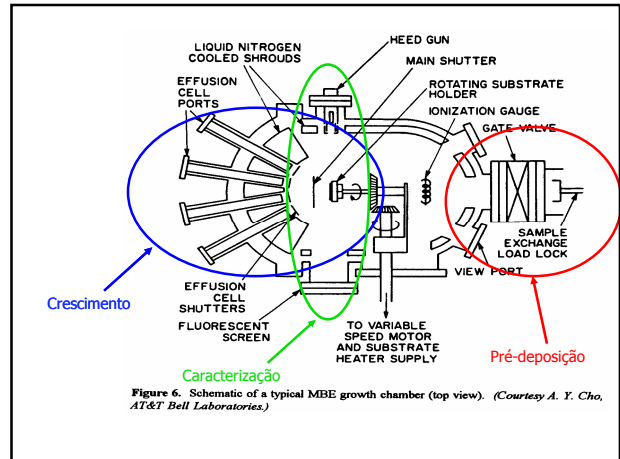
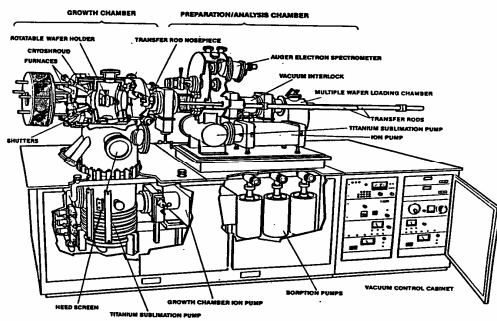
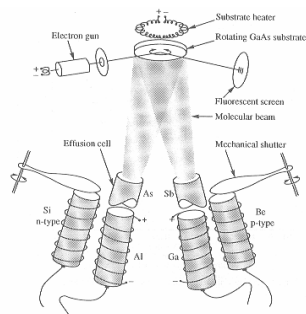



Figure 6. Schematic of a typical MBE growth chamber (top view). (Courtesy A. I. Cho, AT&T Bell Laboratories.)



Esquema: Deposição M.B.E.

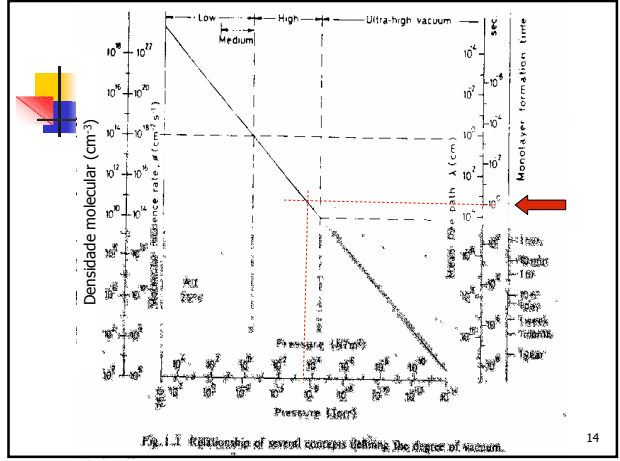

Epitaxia por Feixe Molecular (MBE)

1. Pré-deposição

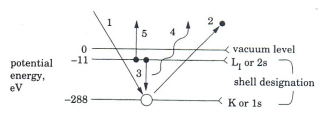


Vácuo
/formação de monocamada
/pressão residual

13

■ Espectroscopia de Elétron Auger (AES)



potential energy, eV

vacuum level

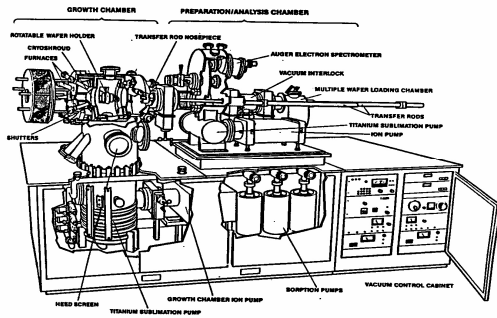
shell designation

L_1 or $2s$

K or $1s$

Figure 6.10 Electron and photon interactions in carbon: (1) probe beam, (2) ejected electron, (3) vacancy filling, (4) fluorescent photon, and (5) Auger electron.

Sistema de MBE



Epitaxia por Feixe Molecular (MBE)

2. Crescimento

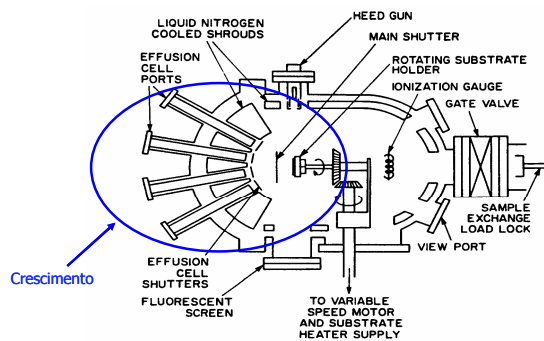
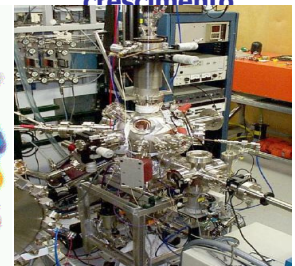
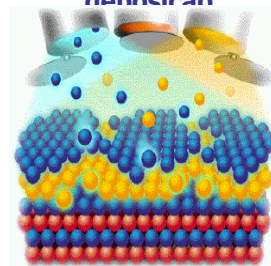


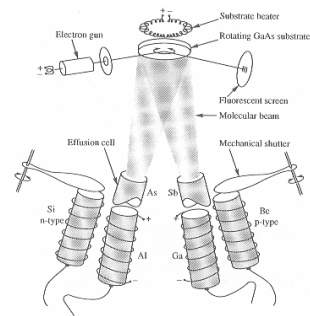
Figure 6. Schematic of a typical MBE growth chamber (top view). (Courtesy A. Y. Cho, AT&T Bell Laboratories.)

Epitaxia MBE

Simulação de densificação

Câmara de crescimento





Esquema: Deposição M.B.E.

Células de Efusão – (Knudsen)

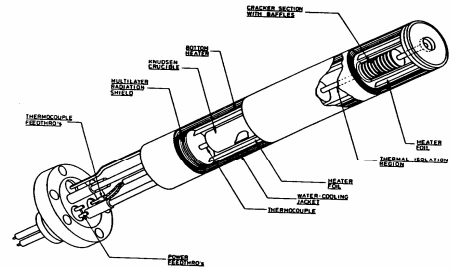


Figure 8. Conventional high temperature As cracker effusion cell consisting of a low temperature sublimation and high temperature cracking zone. (From Ref. 9.)

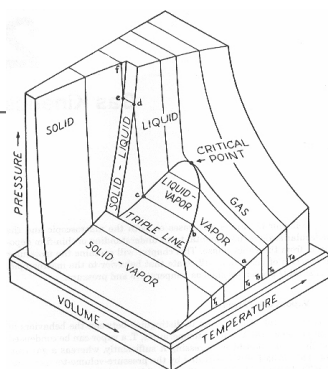
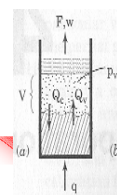


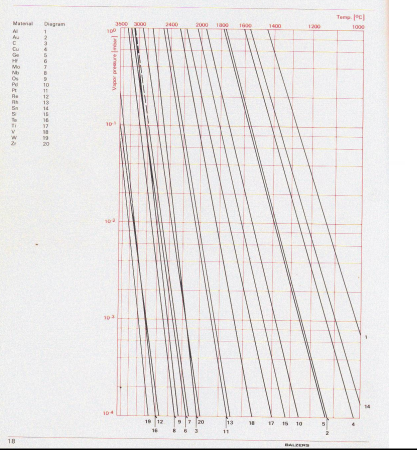
Figure 21 p-V-T diagram for a fixed amount of pure material. (Reprinted from Sears (1950) with permission of the publisher. © 1950, 1953 by Addison-Wesley Publishing)



$$\frac{dp}{dT} \approx \frac{L_v}{R.T^2}$$

$$p(T) = p_0 \cdot e^{-L_v/RT}$$

Pressões de vapor - metais.
Catálogo Balzers



Célula de Knudsen - esquema

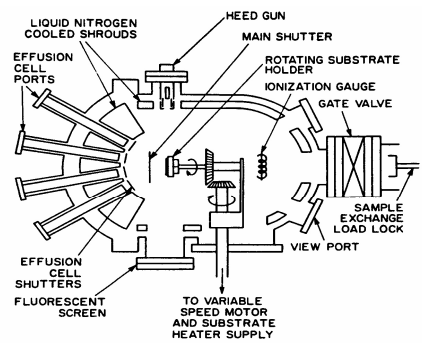
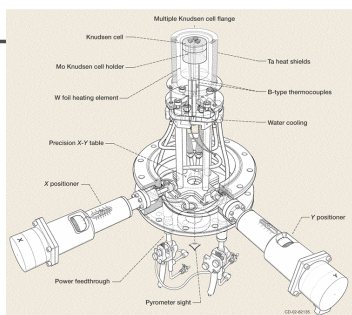
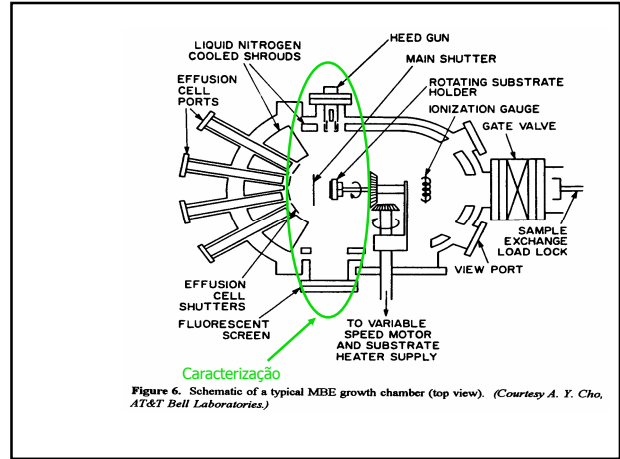


Figure 6. Schematic of a typical MBE growth chamber (top view). (Courtesy A. Y. Cho, AT&T Bell Laboratories.)

Epitaxia por Feixe Molecular (MBE)

3. Caracterização das camadas em crescimento



LEED Si (2x1)

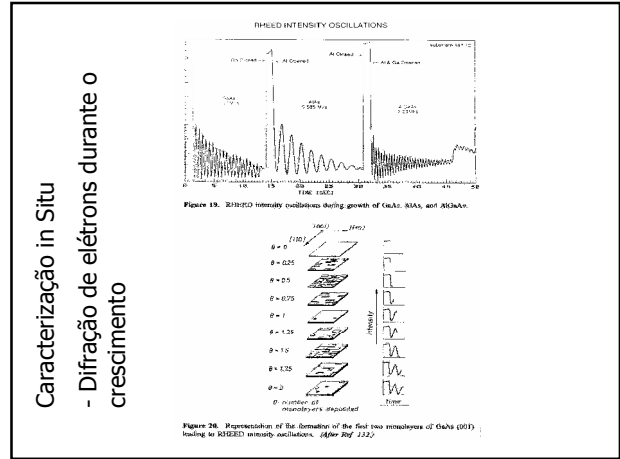
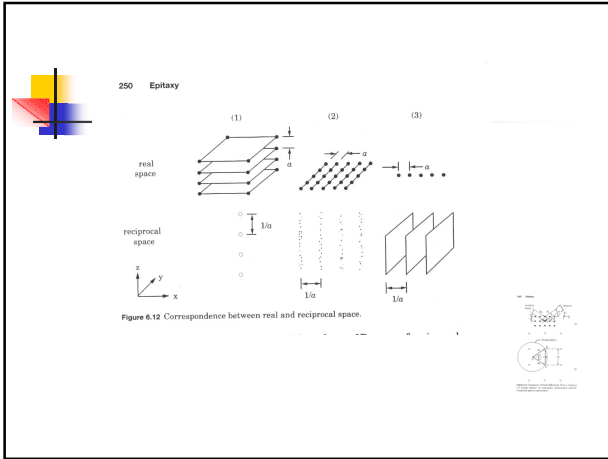
Canhão de elétrons - LEED

Figure 1. LEED pattern of a 1×1 reconstructed surface. The underlying lattice is a square lattice while the surface reconstruction has a 2×1 periodicity. As discussed in the text, the pattern shows that reconstruction occurs in symmetrically equivalent domains which are oriented along different crystallographic axes. The diffraction spots are generated by backscattering of elastically scattered electrons onto a hemispherical fluorescent screen. Also seen is the electron gun which generates the primary electron beam. It carries up parts of this screen.

33

Caracterização in Situ - Difração de elétrons durante o crescimento

Figure 13. RHEED patterns obtained by 15 keV electron beam from GaAs (001) surface 2×2 (left) and 1×1 (right) reconstructed. The patterns are obtained in [110] azimuth (a and c) and [-110] azimuth (b and d). The arrows indicate the positions of bulk-like (unreconstructed) spots. (Courtesy A. I. Cho, AT&T Bell Laboratories.)



- Componentes essenciais da técnica de MBE
- Células de Efusão / Fontes
 - Substratos / Epitaxia
 - Caracterização "in situ"
 - Vácuo
- 35

Finalizando...

- Pontos importantes MBE

36

1. MBE – maior controle

2.

Tradicional:

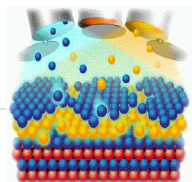
Síntese]]] [[[Processamento

Avançado:

{{{ Síntese ↔ Processamento}}}

3. Controle ↔ "Simplicidade"

37



Obrigado pela atenção!

POSMAT/2012
Prof. José Humberto Dias da Silva

38