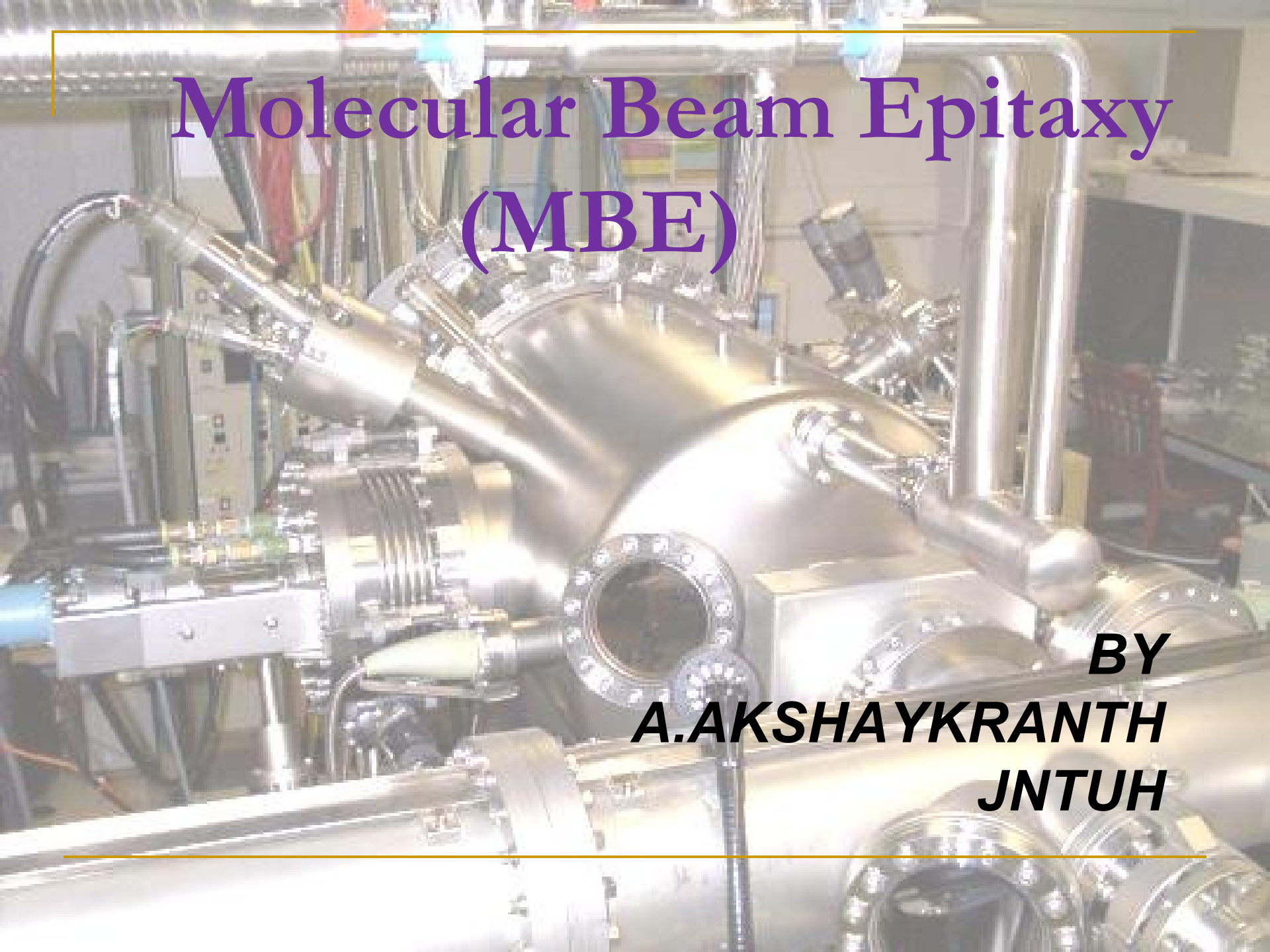
Molecular Beam Epitaxy (MBE)



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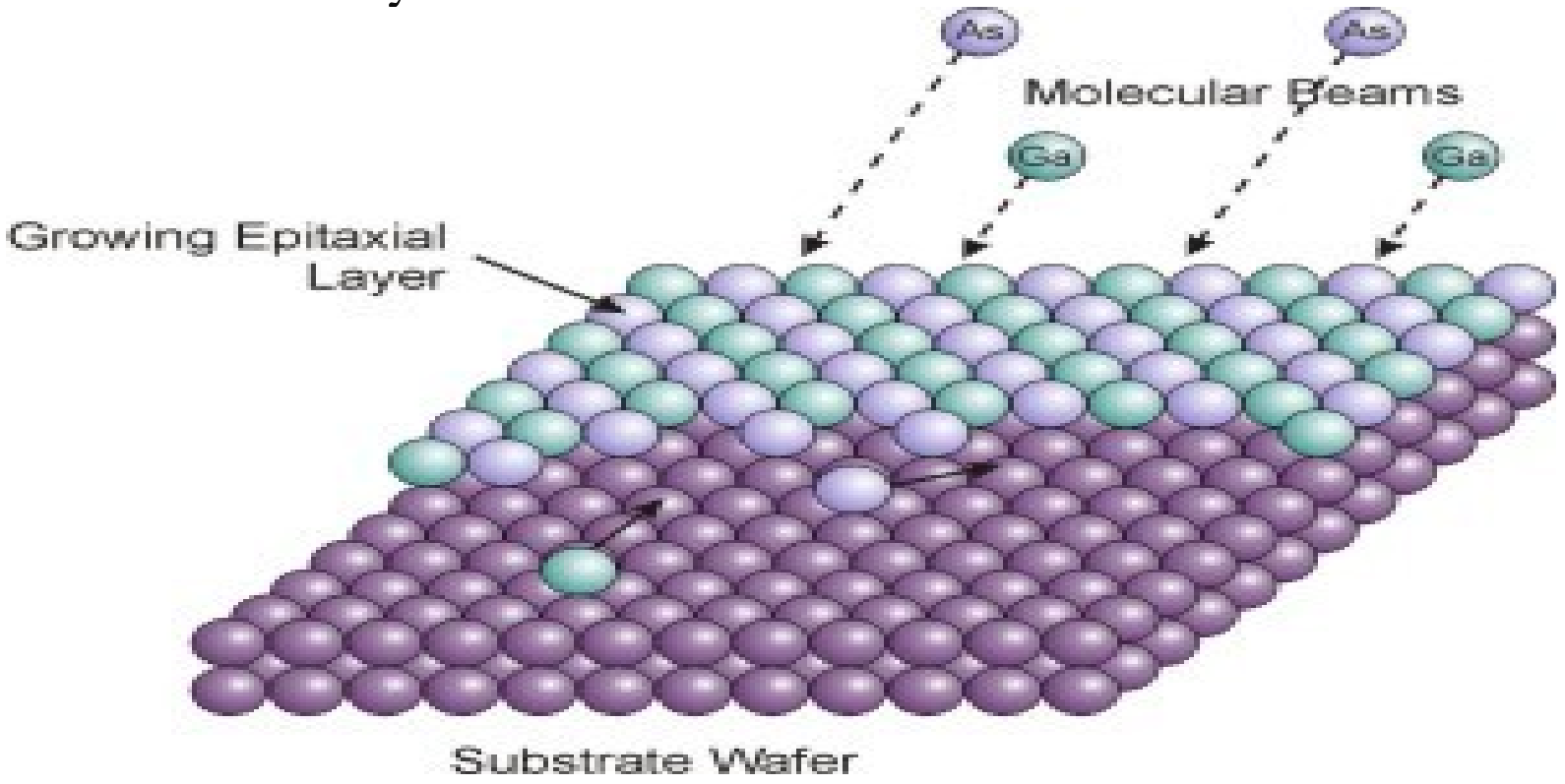
CONTENTS

What is Epitaxy?

- Method of depositing a mono crystalline film i.e deposition and growth of mono crystalline layers.
- Epitaxial : Growing crystalline layers on a crystalline substrate.
- Greek root : ‘epi’ means ‘above’ and ‘taxis’ means ‘ordered’

Molecular beam Epitaxy is a technique for epitaxial growth via the Interaction of one or more molecular or atomic beams that occur on a surface of a heated crystalline substrate.



Epitaxy types:

1.Homoepitaxy: Substrate & material are of same kind, means same composition.(si-si)
To fabricate layers with different doping levels.

2.Heteroepitaxy: Substrate & material are of different kinds, means different composition (Ga-As).
To fabricate integrated crystalline layers of different materials

Epitaxy Techniques

- *Vapor-Phase Epitaxy (VPE)*
  - Modified method of chemical vapor deposition (CVD).
  - Undesired polycrystalline layers
  - Growth rate: ~2 μm/min.

- *Liquid-Phase Epitaxy (LPE)*
  - Hard to make thin films
  - Growth rate: 0.1-1 μm/min.

- *Molecular Beam Epitaxy (MBE)*
  - MBE is an ultra high vacuum(UHV) based technique for producing high quality epitaxial structures with mono layer (ML) control.
  - "Beam" molecules do not collide to either chamber walls or existent gas atoms.
  - We do MBE In a vacuum chamber (pressure: ~10^{-11} Torr).
  - Growth rate: 1μm/hr.

Why we go for MBE ?

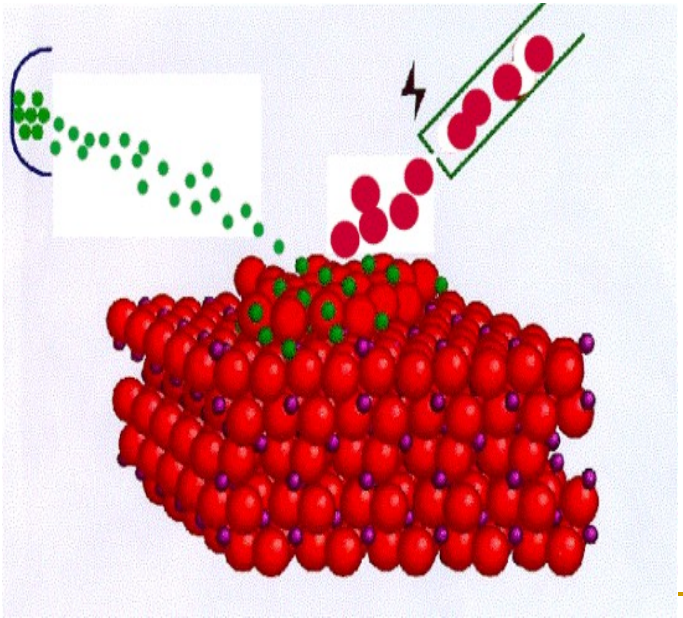
- This technique for producing epitaxial layers of metals, insulators , and super conductors as well as both at the reserch and industrial production level.

MBE: Working Principle

1.MBE:process: the term 'beam' means the evaporated atoms do not interact with each other or with other vacuum chamber gases until they reach the wafer.

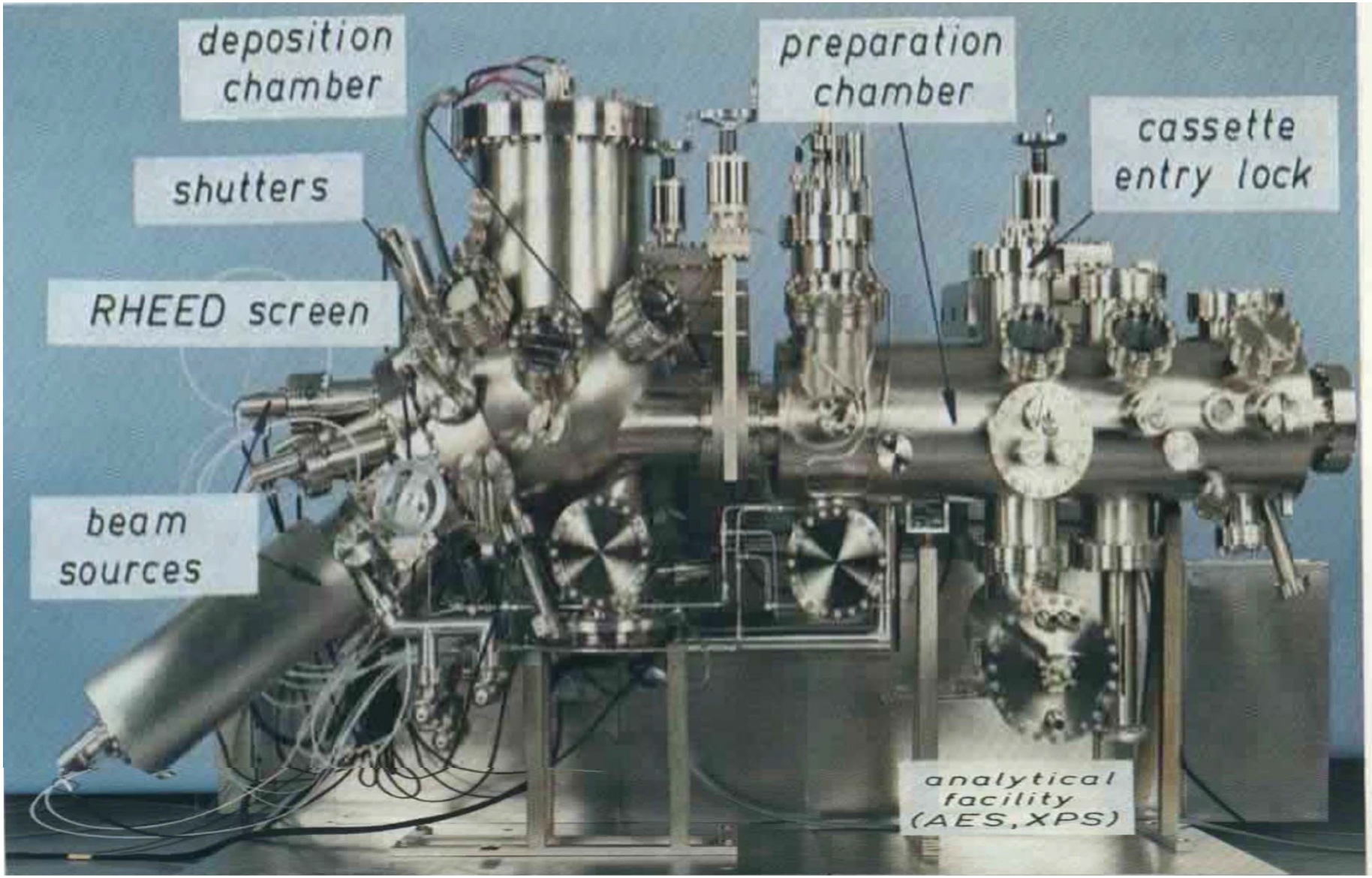
- Ultra pure elements are heated in separate quai- effusion cells (e.g ga and as) until they begin to slowly sublimate.

2.Epitaxial growth: Epitaxial growth takes place Due to the interaction of molecular or atomic beams on a surface of a heated crystalline substrate.



Molecular Beam Epitaxy**

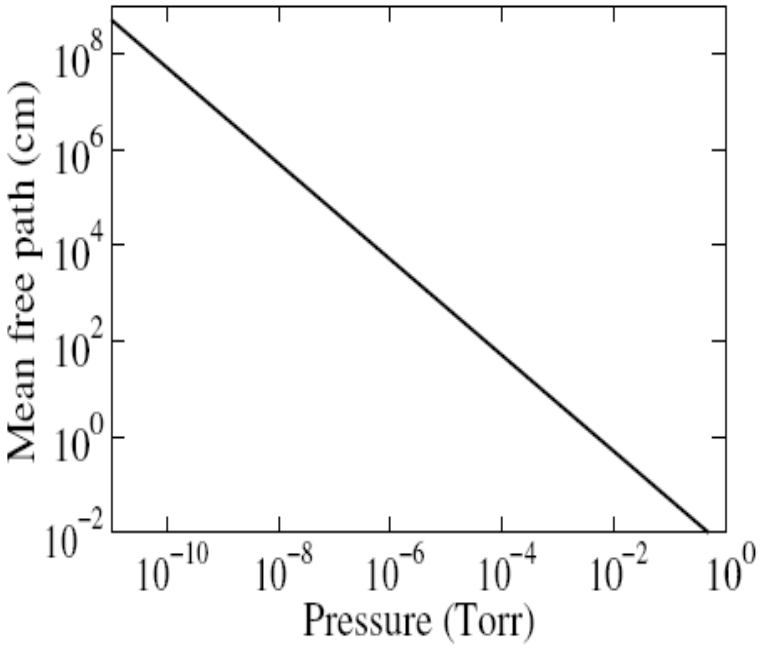
- They provide an angular distribution of atoms or molecules in a beam.
- The substrate is heated to the necessary temperature.
- Atoms on a clean surface are free to move until finding correct position in the crystal lattice to bond.



A commercial MBE system

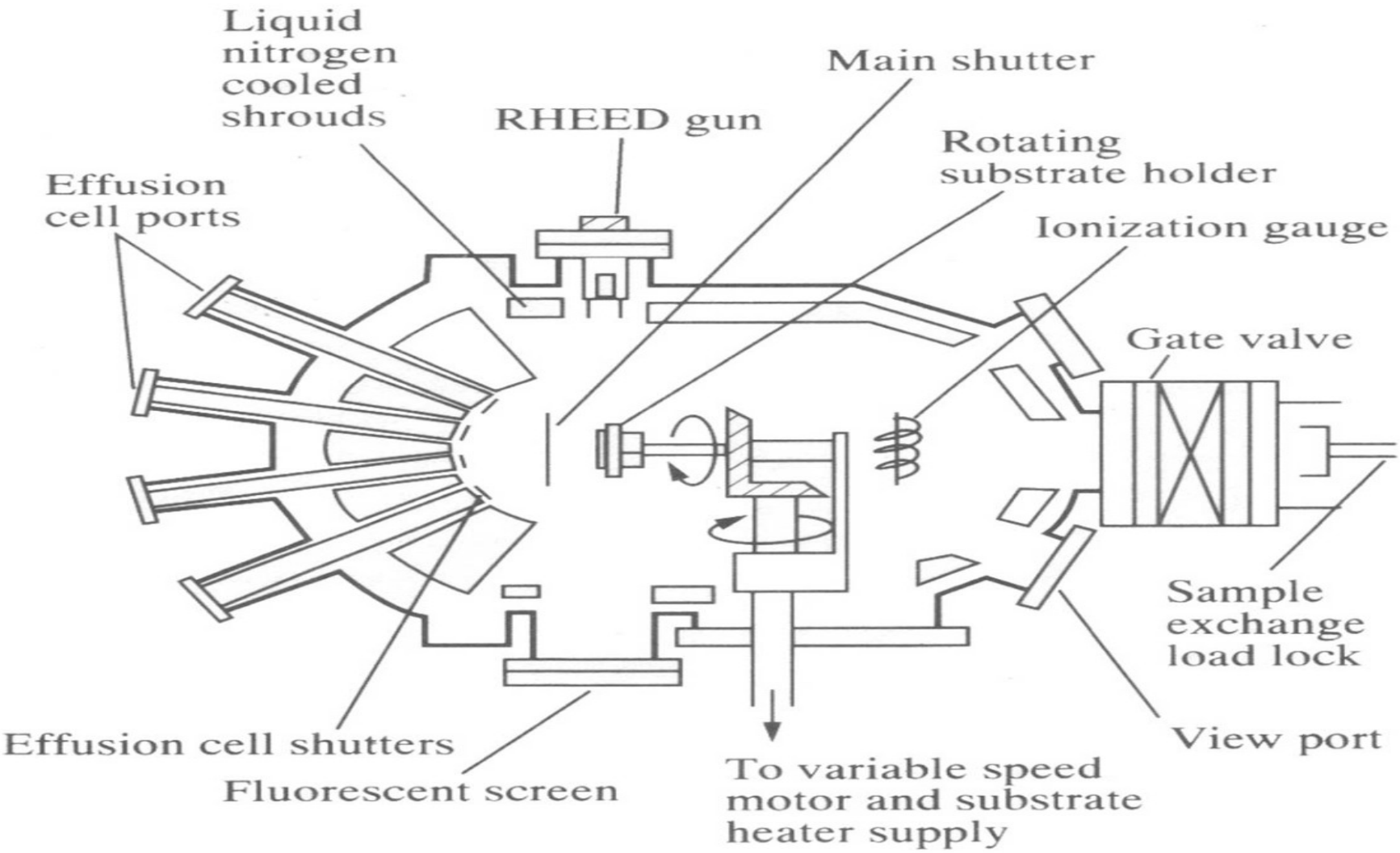
MBE: Working Conditions

- The mean free path (λ) of the particles > geometrical size of the chamber.



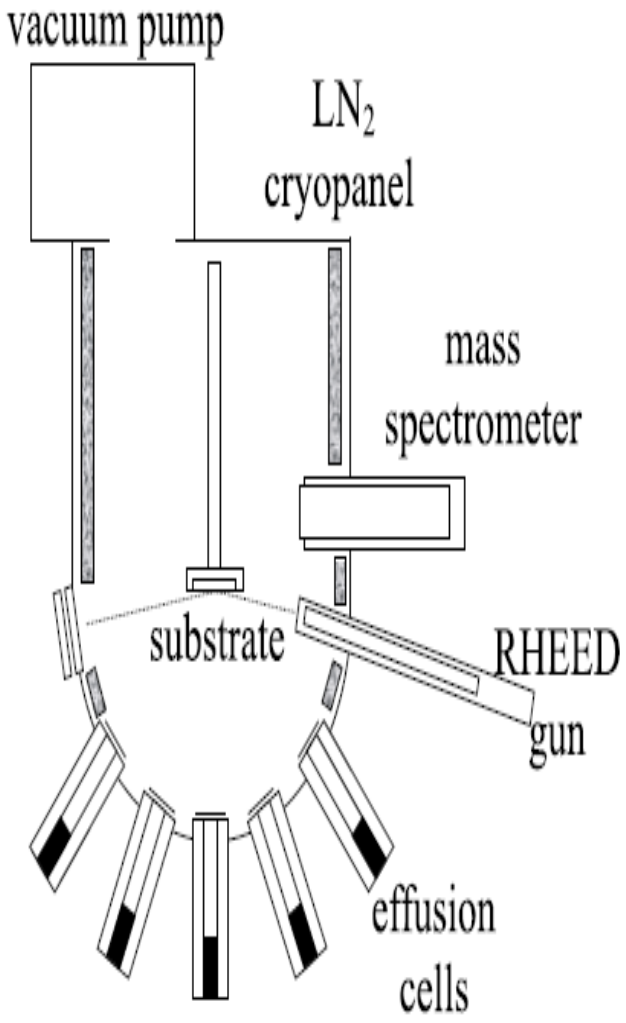
Mean free path for Nitrogen molecules at 300 K *

- That is easily fulfilled if the total pressure does not exceed 10^{-5} torr.
- It is also the condition for growing a sufficiently clean epilayer.



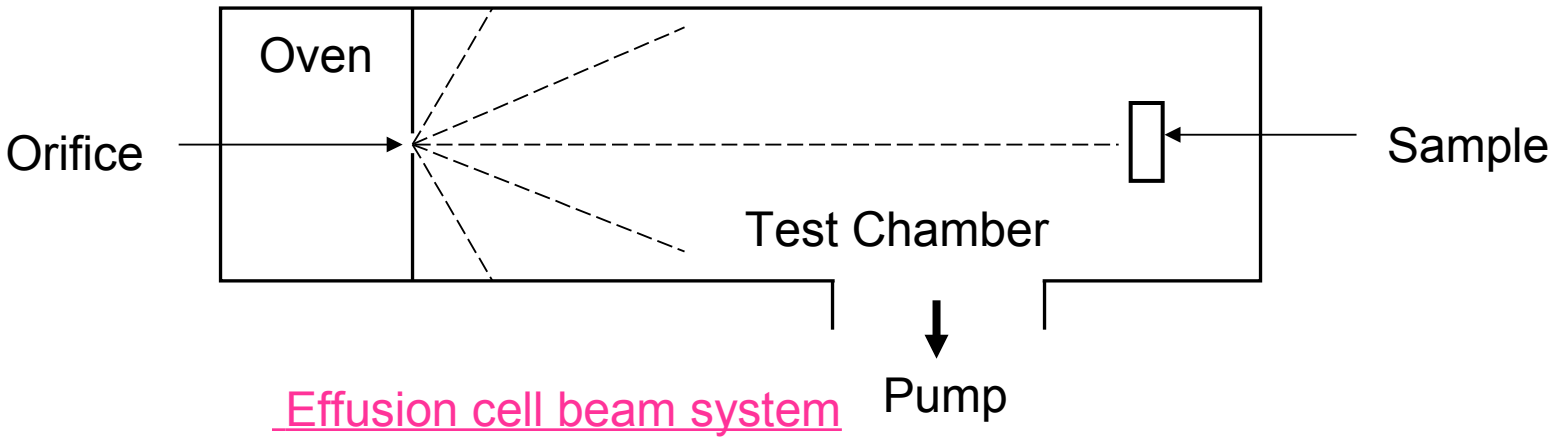
Some attributes of MBE Chambers

MBE: Operation



- The vacuum system consist in a stainless-steel growth chamber.
- The pumping system usually consists of ion pumps, cryogenic pumps for the pumping of specific gas species.
- Ultra high vacuum is used to obtain sufficiently clear epilayer

Effusion cell :



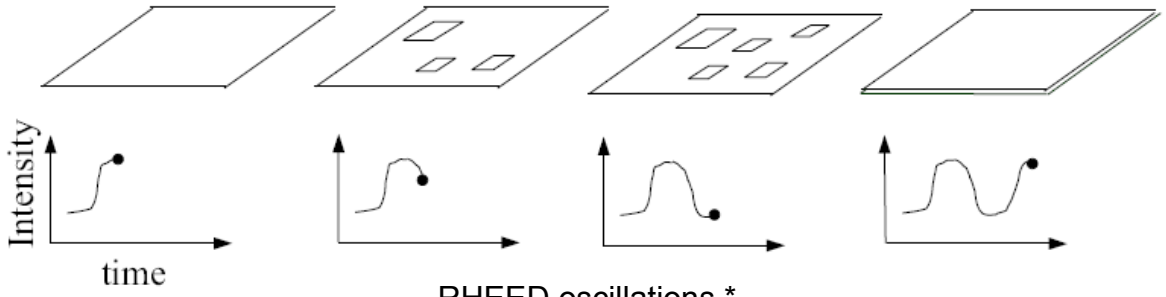
Effusion cell beam system

- Effusion cells are the key components of an MBE system, because they must provide excellent flux stability and unifomity and material purity.
- A collection of gas molecules moving in the same direction.
- Oven contains the material to make beam.
- Oven is connected to a vacuum system through a hole.
- The substrate is located with a line of sight to the oven aperture

MBE: Control Mechanisms

- MBE systems permit the Control of composition and doping of the growing structure at monolayer by changing the nature of the incoming beam just by opening and closing mechanical shutters.

- The operation time of a shutter is approximately 0.1s ,that is much shorter than the time needed to grow one mono layer(typically 1-5s).
- Molybdenum and tantalum are widely used for shutters.
- what is RHEED
- RHEED (Reflection High Energy Electron Diffraction) for monitoring the growth of the crystal layers.



RHEED oscillations *

Benefits and Drawbacks of MBE

Benefits

- Clean surfaces, free of an oxide layer.
- *good control of layer thick ness and composition.*
- Low growth rate (1μm/h),
So, we get high material purity.
- Precisely controllable thermal evaporation.
- Seperate evaporation of each component takes place.
- Substrate temperature is not high.

Draw backs

- Expensive (10^6 $ per MBE chamber)
- Very complicated system
- Epitaxial growth under ultra-high vacuum conditions

Applications

- Hetero junction bipolar transistors(HBT's) used in satellite communications.
- Electronic and optoelectronic devices (LED's for laser printers, CD and DVD players).
- Used in the construction of quantum wells , dots and wires for use in lasers.
- To build a solar cell by depositing a Thin film of a photo voltaic material
- Low temperature Super conductor.

Conclusions

- Objective: to deposit single crystal thin films
- Typically in ultra-high vacuum
- Deposition rates are very low (1μm/hr)
- Very well controlled (Shuttering: 0.1s)
- Film growth with good crystal structure

- Deposition rate is so low that substrate temperature doesn't need to be as high.

- Expensive

VIDEOS OF MBE

ANY QUERIES

THANK YOU