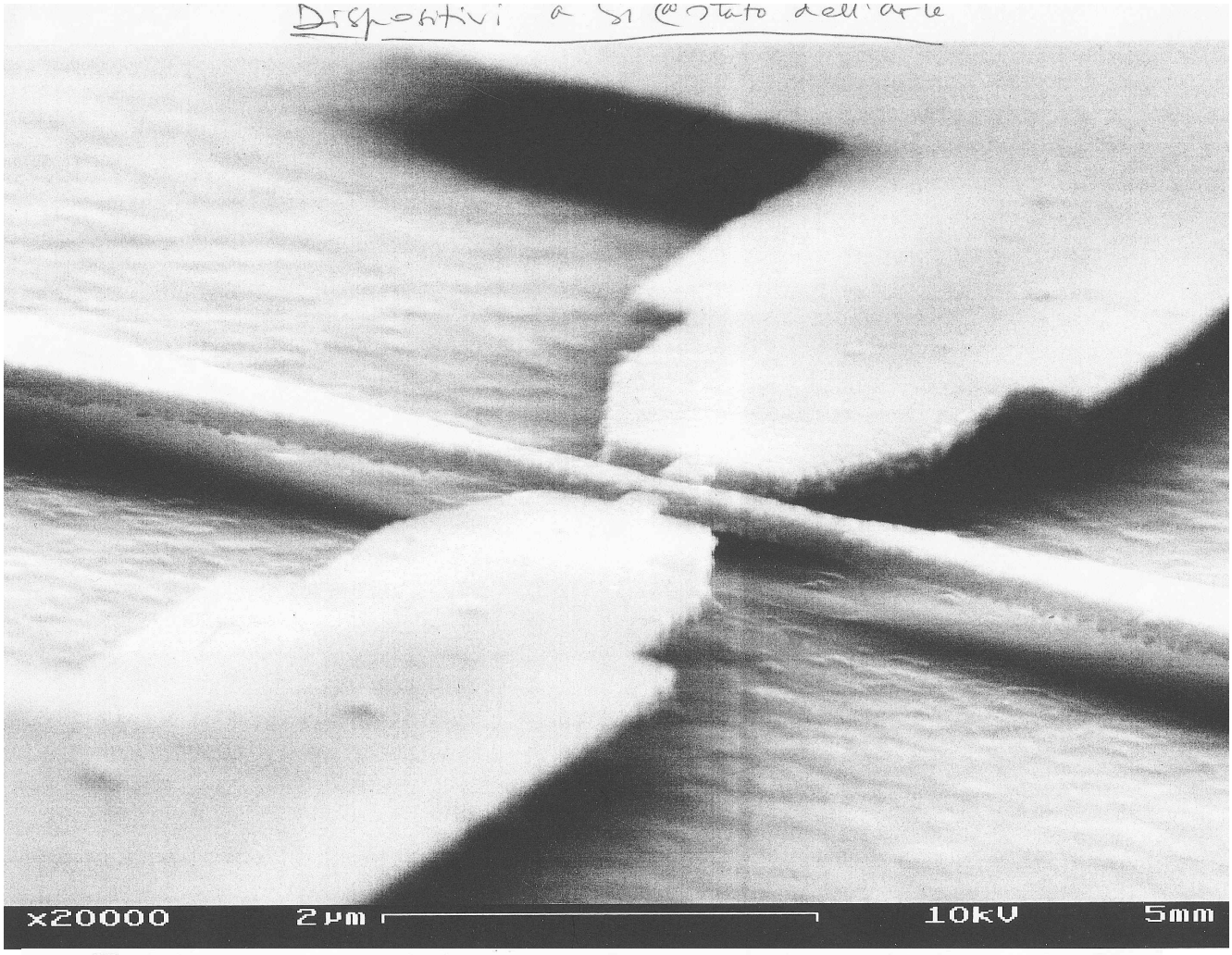
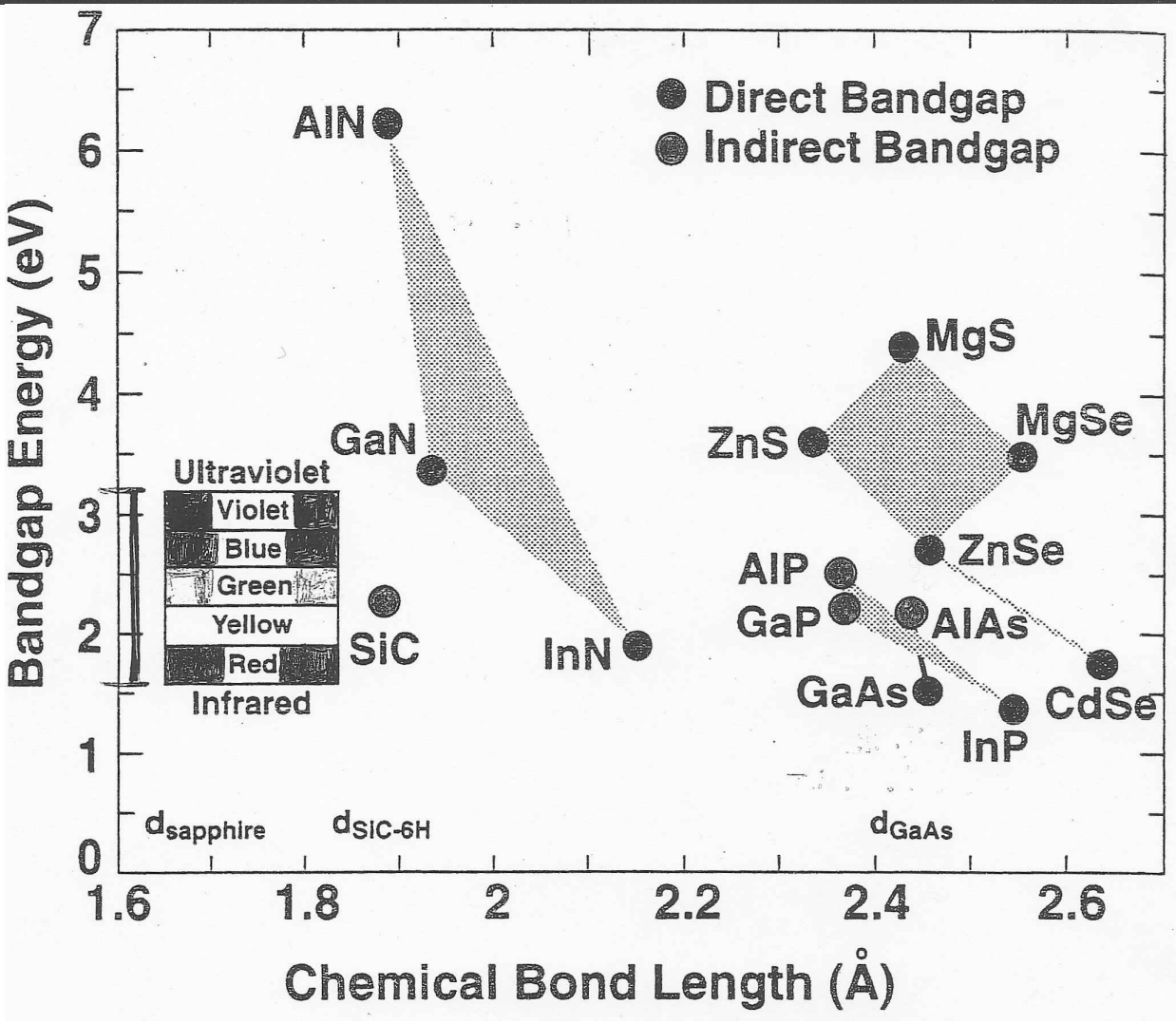
Dispositivi a Si @ stato dell'arte



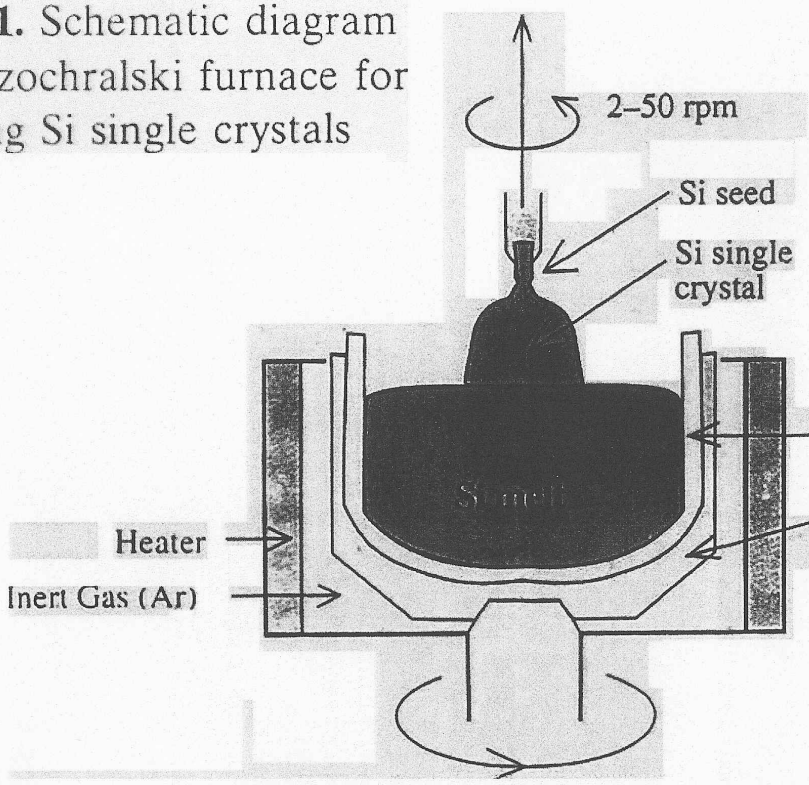


Growth Techniques

- **Czochralski Method** (LEC) (Bulk Crystals)
- **Chemical Vapor Deposition** (CVD) (Thin films; epitaxial film growth)
  - Metal-Organic Chemical Vapor Deposition (MOCVD
- **Molecular Beam Epitaxy** (MBE) (Thin films)
- **Liquid Phase Epitaxy** (LPE) (Thin films)

Czochralski Method

Fig. 1.1. Schematic diagram of a Czochralski furnace for growing Si single crystals



Bridgeman Method
a temperature gradient along the crucible

↑ growth speed
~ 2 - 3 mm/minute

O, C are contaminants!

Liquid-Encapsulated Czochralski (LEC) Method. As expected, LEC-grown GaAs often contains boron as a contaminant.

Thin Film Growth

(General)

- **High Quality Film** (**1μm** or less thickness) deposited on high quality substrate.
- To **minimize strain**, need crystal structure of film & substrate to be ~ same (at least very similar

- Epitaxy: "in an ordered way"
  Homoepitaxy: same structure as substrate
  Heteroepitaxy: different structure than substrate

Chemical Vapor Deposition

(CVD)

- **Example** reaction:

$$\underset{\text{(Silane gas)}}{SiH_4\ (heat)} \longrightarrow \underset{\text{(On substrate)}}{Si} + \underset{\text{(gas)}}{2\,H_2}$$

- Reaction occurs in a **sealed container (reactor)**
- ***NOTE!!*** Silane gas is highly toxic & highly explosive!!
- ***NOTE!!*** Hydrogen gas is highly explosive!!!!

Metal-Organic Chemical Vapor Deposition

(MOCVD)

- **Example** reaction:

$$\underset{\text{(Metal-organic gas)}}{Ga(CH_3)_3} + \underset{\text{(Arsene gas)}}{AsH_3} \longrightarrow$$

$$3CH_4 + GaAs$$

(Methane gas) (on substrate)

- Reaction occurs in a **sealed container (reactor)**
- ***NOTE!!*** Arsene gas is highly toxic and highly flamable!! Methane gas is highly explosive!

Molecular Beam Epitaxy
(MBE)

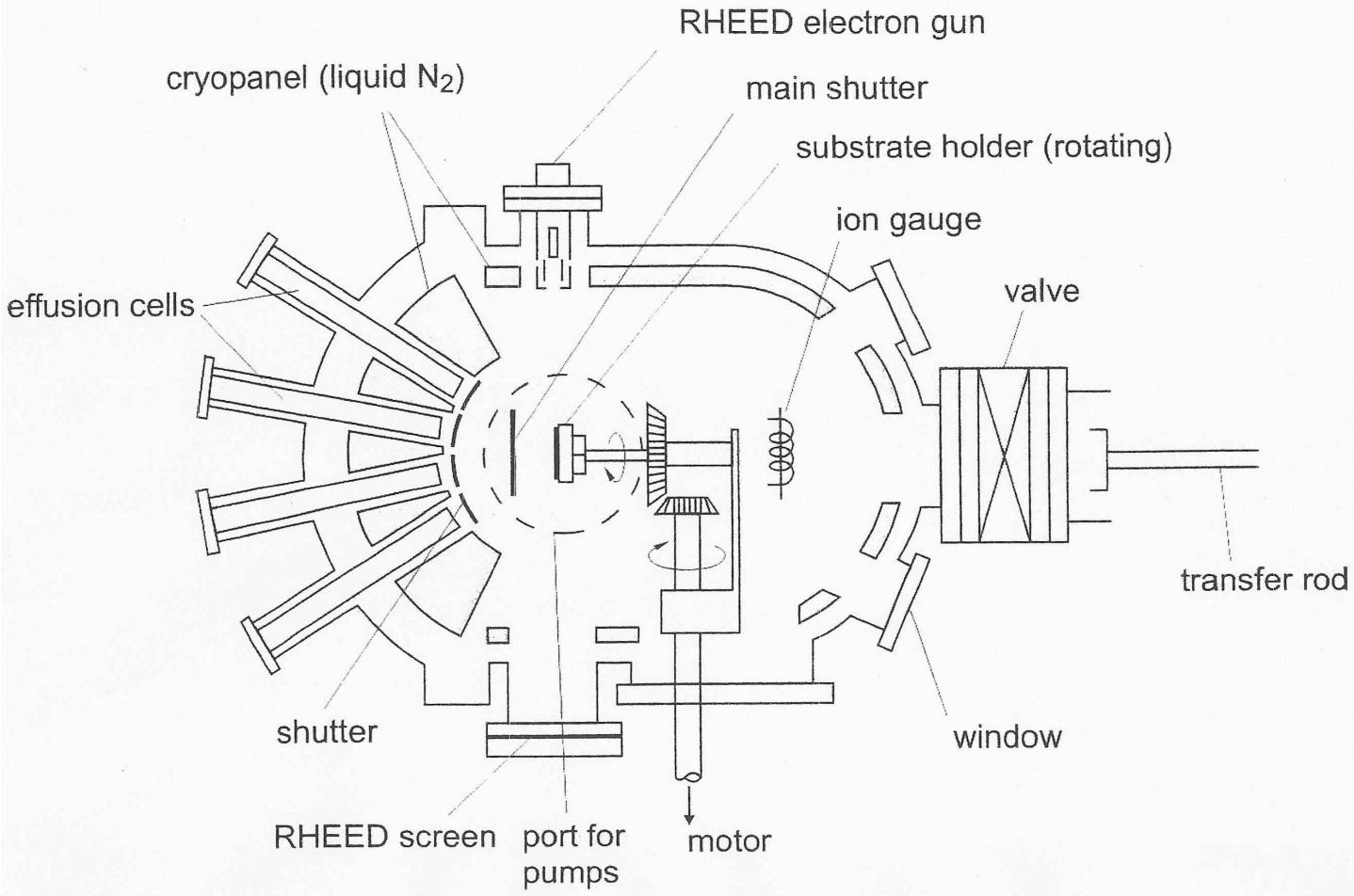
- Thin film growth under ***ultra high vacuum***.
- Reactants introduced by **molecular beams.**
- Create beams by heating source of material in an effusion (or Knudsen) cell.
- Several sources, several beams of different materials aimed at substrate

Can deposit 1 atomic layer or less!

- A very precisely defined mixture of atoms to give ***EXACTLY*** the desired material com

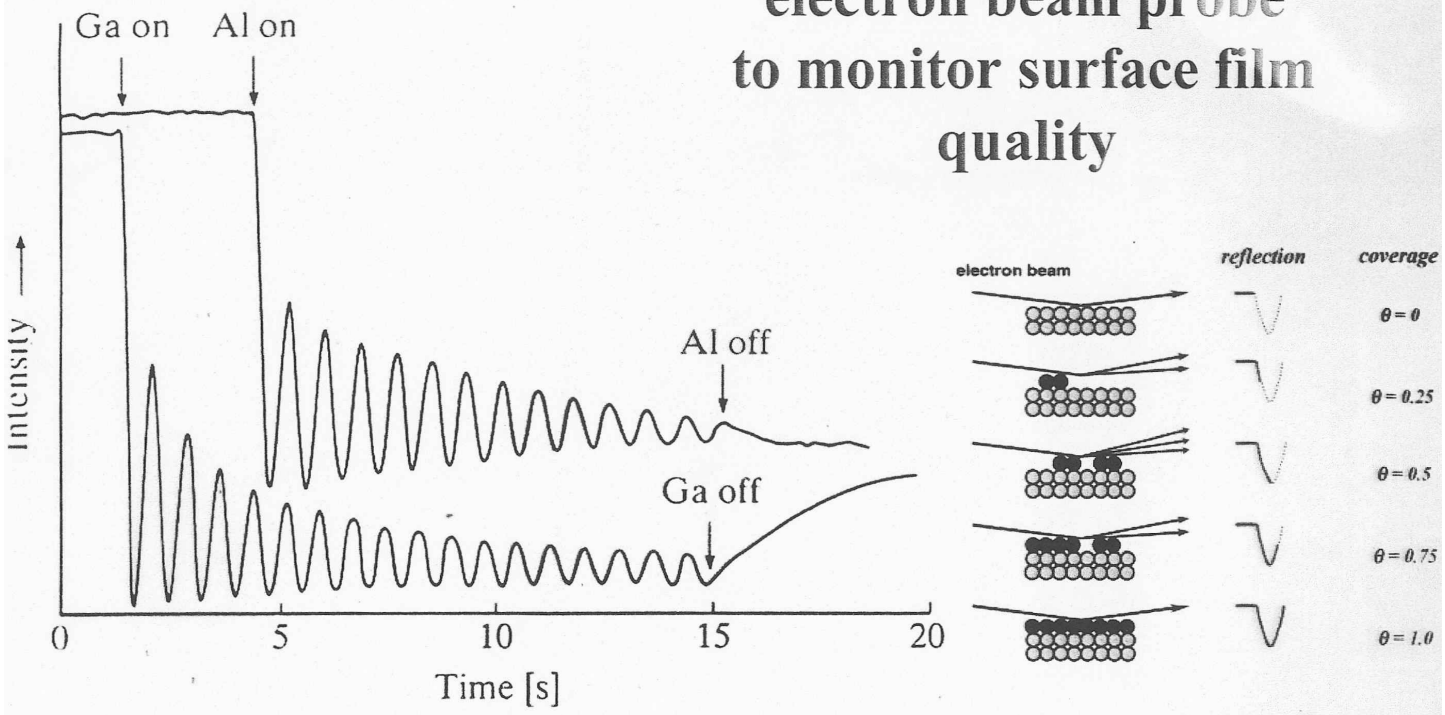
MBE Reactor

Vacuite
AR MBE



RHEED: Used with MOCVD & MBE

electron beam probe to monitor surface film quality



One period of oscillation ≡ growth of one atomic layer of GaAs (or whatever material)

MOCVD vs. MBE

MBE

- Mainly useful for research lab experiments. Not efficient for mass production!
- High quality pressure in the reactor 10^{-11} mbar
- Low growth rate ~1 μm/h
- High homogeneity

MOCVD

- Useful for lab experiments and for mass productio
- Good-high quality
- High growth rate (~)