EPITAXY

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INTRODUCTION

- **Epitaxy**, a transliteration of two greek words "**epi**", meaning "**upon**" and "**taxis**" meaning "**ordered**", is a term applied to processes used to grow a thin crystalline layer on a crystalline substrate.
- When a material is grown epitaxially on a substrate of same material, such Si grown on Si, the process is called **"homoepitaxy".**
- If the layer and substrate are of different material, such as AlGaAs on GaAs, the process is "**heteroepitaxy**"

INTRODUCTION

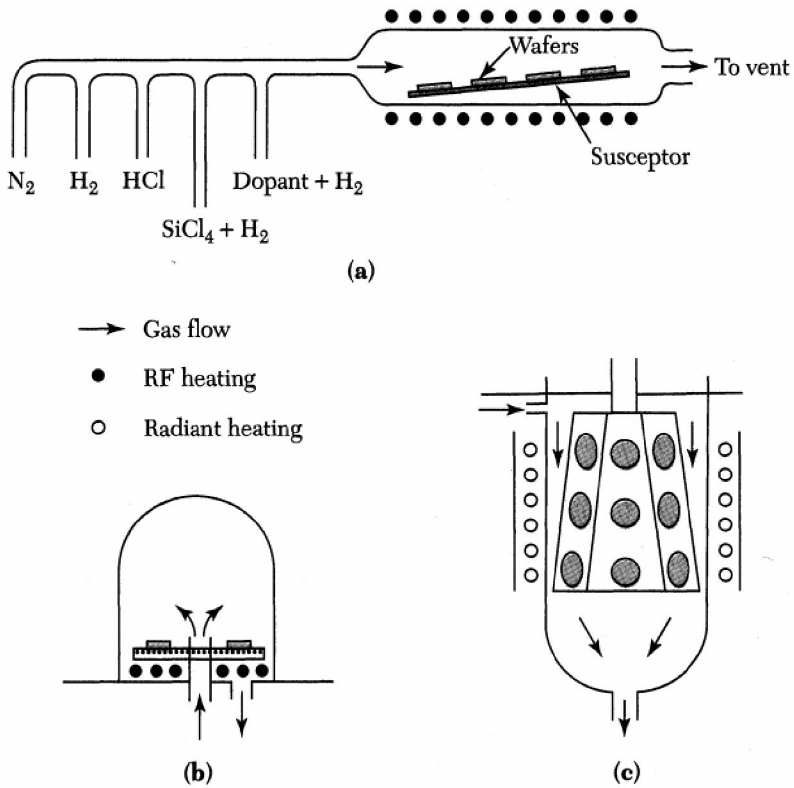
- In an epitaxial process, the substrate wafer acts as the seed crystal.
- Epitaxial processes are differentiated from the melt-growth processes described in previous sections in that the epitaxial layer can be grown at a temperature substantially below the melting point,typically3040% lower.
- The common techniques for epitaxial growth are chemical-vapor deposition (CVD) and molecular-beam epitaxy (MBE).

VAPOUR PHASE EPITAXY

- Among other epitaxial processes, VPE is most important case of Si device and to some extent to GaAs also.
- The vapour deposition of single crystal silicon is performed in a reactor which consist of a quartz reaction chamber into which susceptor is placed.
- The susceptor are made from graphite blocks whether it is of horizontal, pancake or barrel shape. They give mechanical support to the wafer and in the induction heated reactor they also serve as the source of thermal energy for reaction.
- This is high temperature process at which deposition take place after several chemical reactions.

VAPOUR PHASE EPITAXY

- The commonly used susceptor for epitaxial growth are shown below.



) Three common susceptors for chemical vapor deposition: (*a*) horizontal, (*b*) pancake,) barrel susceptor.

VAPOUR PHASE EPITAXY

- **Horizontal reactor** offer lower cost construction, but controlling the deposition process throughout the length of the susceptor is a problem.
- **Pan cake reactor** are capable of uniform deposition but they suffer from mechanical complexity.
- **Barrel reactor** are also used for uniform deposition .but are not suitable at temperature above 1200 degree C.

VAPOUR PHASE EPITAXY

- The most of the reactor
  - Reaction tube are relatively cool during operation. Forced air cooling is done. Induction coils and the metal parts of the reactor are water cooled.
  - Energy for the reaction is supplied by heating the susceptor inductively and the energy is transported to the wafer by conduction and radiation. Radiant heating provides more uniform heating than conductive heating.The energy is supplied by banks of quartz halogen lamp.

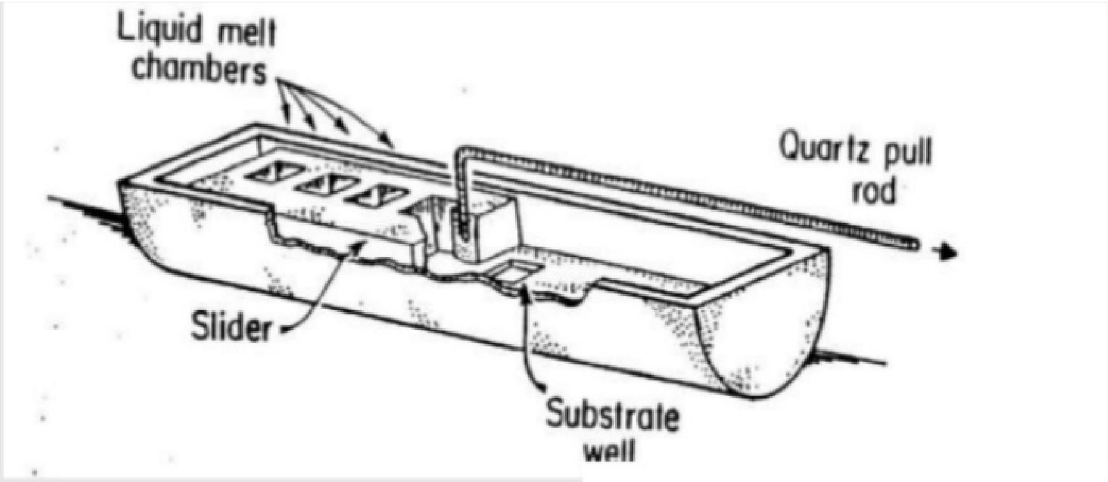
VAPOUR PHASE EPITAXY

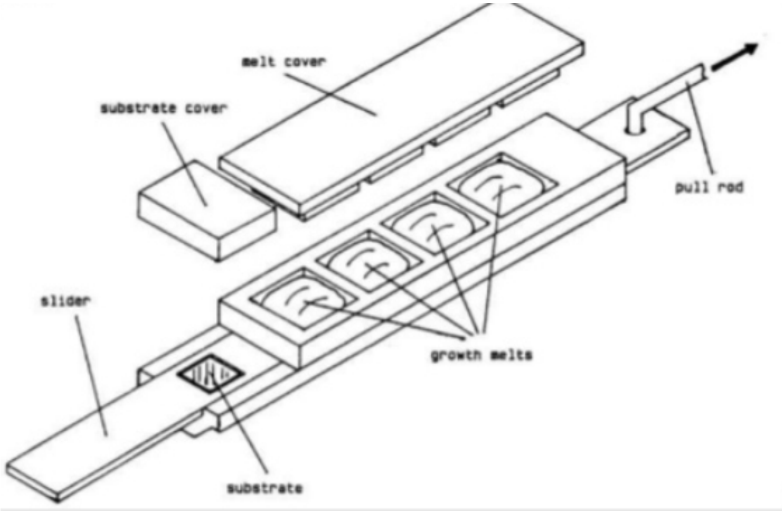
- **Steps involved in typical epitaxial process**
  - The hydrogen carrier gas perges the air of reactor.
  - The reactor is heated to the required temperature.
  - An HCl etch take place at the temp between 1150 to 1200 degree C.
  - Then temperature is reduced to the growth temperature and flushing HCl take place.
  - Si source and dopant flows are turned on and growth proceeds.
  - After growth, the dopant and Si flow are removed and temperature reduces.
  - The hydrogen flow is replaced by a nitrogen flow to remove the wafer.

Liquid phase Epitaxy

- When the growth of epitaxial layer on crystalline substrate by direct precipitation from liquid phase take place, it is known as **Liquid Phase Epitaxy.**
- This technique is mainly used for growing gallium arsenide and other III-V compounds. It is also useful in growing very thin epitaxial rate as growth rate is very small.
- The boat configuration for liquid phase epitaxy is shown in fig. In this one or more well are machined in a high purity graphite block which serve to hold the reactant solution. A graphite slider holding the substrate is moved so as to locate them under the wells.

LIQUID PHASE EPITAXY





Liquid phase Epitaxy

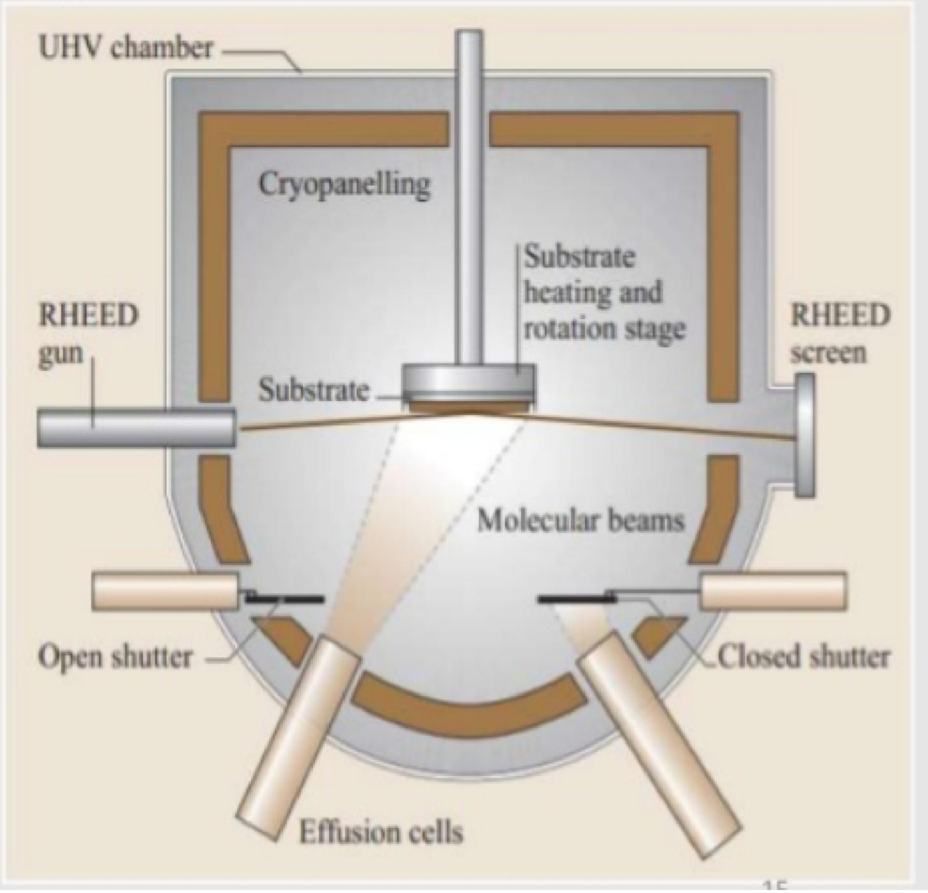
- This is placed in a furnance, in a neutral carrier gas (hydrogen) ambient.
- At a required temperature the substrate is moved under the first well and the temperature of the furnance is lowered. The wafer is moved out from under the solution to stop the growth. For growing additional layer the substrate is moved successively under the well.
- One of the basic requirement of liquid phase epitaxy is that the material to be grown dissolves in a solvent and the solution must melt at a temperature well below the MP of the semiconductor substrate.

Molecular Beam Epitaxy

- Molecular beam epitaxy uses an evaporation method and involves the reaction of one or more thermal beams of atoms or molecules with a crystalline surface under ultra-high vaccum condition .This process is used to achieve precise control of channel composition and doping profile.
- Schematic of MBE growth system is shown in fig below.

Molecular Beam Epitaxy

- basic elements of MBE system:
  1) Heated substrate
  2) Effusion cells and shutter
  3) Reflection High Energy Electron Diffraction (RHEED system- RHEED gun & screen)
  4) Ultra High Vacuum (UHV)
  5) Liquid Nitrogen cryopanelling



Molecular Beam Epitaxy

- The evaporation species are at relatively high velocity in a vacuum to the substrate. Since collision between atom are not important in a high vacuum, transport velocity is controlled more by thermal energy effects than by diffusion effects and its uniformity can be controlled by source characteristics.
- The temperature range for MBE is from 400 to 800 degree C.

Molecular Beam Epitaxy

- Cleaning for MBE is done by
  - High Temperature baking between 1000 degree C - 1250 degree C decomposes material oxide and remove other absorbed species by evaporation or diffusion into the wafer.
  - Use of low energy beam of an inert gas to sputter clean the surface