EE 527 MICROFABRICATION

Lecture 13

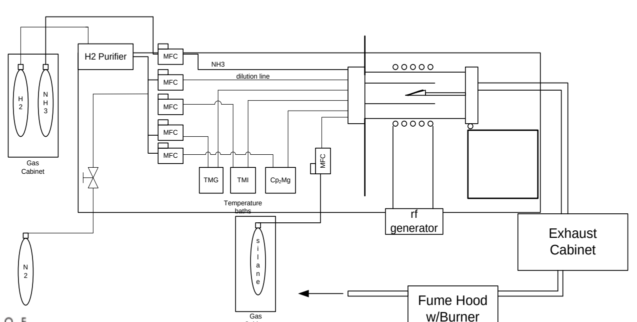
Tai-Chang Chen
University of Washington

EPITAXY/VAPOR-PHASE EPITAXY (MOCVD)

- Use GaN MOCVD (metal-organic vapor-phase epitaxy) as an example:

A metal-organic gas phase of trimethylgallium reacts with ammonia,

$$(CH)_3Ga\ (g) + NH_3\ (g) \rightarrow GaN\ (s) + 3CH_4\ (g)$$

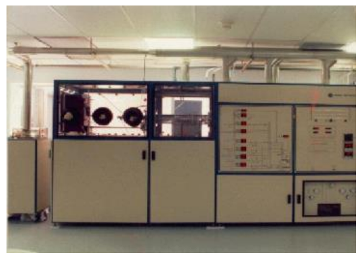


VAPOR-PHASE EPITAXY

- Use GaN MOCVD (metal-organic vapor-phase epitaxy) as an example:

$$(CH)_3Ga + NH_3 \rightarrow GaN + 3CH_4$$

Crystal Specialties 425



EPITAXY/LIQUID-PHASE EPITAXY

A substrate is brought into contact with a saturated solution of the film material at an appropriate temperature. The substrate is then cooled at a suitable rate to lead to film growth.

Example

- Typically compounds and alloys of III-V Semiconductors (similar to MBE)

Advantages

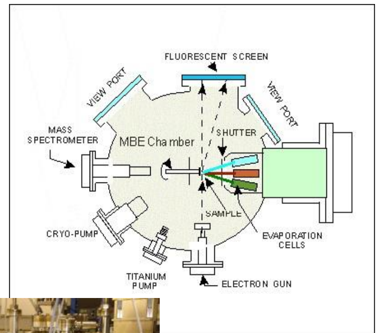
- Less expensive and higher deposition rates
- Low defect concentration
- Excellent control of stoichiometry

Disadvantages

- Solubility considerations greatly restrict the number of materials for which this method is applicable
- Morphology (crystal orientation) control is difficult
- Surface quality often poor

EPITAXY/SOLID-PHASE EPITAXY

- MBE (molecular beam epitaxy):
  - High vacuum required
  - Molecular or atomic beams travel through reactor and constituents impinge upon the substrates.
  - Low temperature growth
  - Low growth rate



http://users.rcn.com/qsa/semicon/mbe.jpg

http://foord.chem.ox.ac.uk/facility/MBE1.jpg

UNIVERSITY OF WASHINGTON

Winter 2014

PATTERN GENERATION (CHAPTER 8)

UNIVERSITY OF WASHINGTON

3

PATTERN GENERATORS

- The first pattern generator consisted of
  - A mechanical stage
  - Aperture blades
  - A UV lamp
- The wafer is covered with photoresist, a layer of photosensitive polymer.
- This method was employed in the early era of microfabrication when linewidths were above 10 µm.
- Even smaller features can be exposed by focused electron or ion beams.
- Electron and laser beam system are the standard tools for pattern generation.

http://www.newport.com/Mask-Alignment-Tools/378209/1033/info.aspx

ELECTRON BEAM LITHOGRAPHY

- Electron beam spots can be as small as in the range of 5 nm.
- Electrons are light mass objects and when they strike photoresist with high energy, they will scatter and broaden the exposed area in the photoresist.
  - Thinner resist would reduce scattering and enhance resolution.
  - Thinner resist might cause the problems during post-lithography processes.
- An approximation to effective beam diameter in resist is given by

$$d_{eff}\,(nm) = 0.9 \times \left(\frac{t}{V}\right)^{1.5}$$

Where resist thickness t and voltage in KV.

- Electron beam lithography is the workhorse of nano- and microfabrication.
- The slow writing speed is a major drawback.

LASER PATTERN GENERATOR

- Laser pattern generators work on similar principles as e-beam systems.
- In general, laser beam writing is faster and cheaper than e-beam writing.
- Laser beams, wavelengths range between visible and UV light, have a wide variety of photoresists.
- Laser pattern technology is used whenever the linewidth resolution is adequate.

PHOTOMASK FABRICATION (8.4)

PHOTOMASK PHYSICAL CONSTRUCTION CONSIDERATIONS

- Cost
- Resolution
- Critical dimension accuracy
- Wear / lifespan
- Illumination wavelength
- Printing method
- Thickness of the plate
- Flatness
- Temperature stability (thermal expansion coefficient)
- Mask polarity

UNIVERSITY OF WASHINGTON

PHOTOMASK GEOMETRICAL DESIGN CONSIDERATIONS - 1

- Wafer size
- Die size
- Die array on wafer
- Device minimum feature size
- Layout grid size
- Floor planning
  - Active device core and standard cell arrays
  - Interconnect channels
  - Bus ring for power distribution
  - Pad frame and wire bonding scheme

UNIVERSITY OF WASHINGTON

PHOTOMASK GEOMETRICAL DESIGN CONSIDERATIONS - 2

Physical layout design rules

- Alignment markers
  - Layer-to-layer and cumulative
  - Visual, coarse, fine, vernier
  - Marker placement
- Proximity and density effects
- Process shrinks and bloats
- Corner compensation
- Process test patterns
- Diagnostic devices and probe pads
- Dicing and packaging marks

UNIVERSITY OF WASHINGTON

7