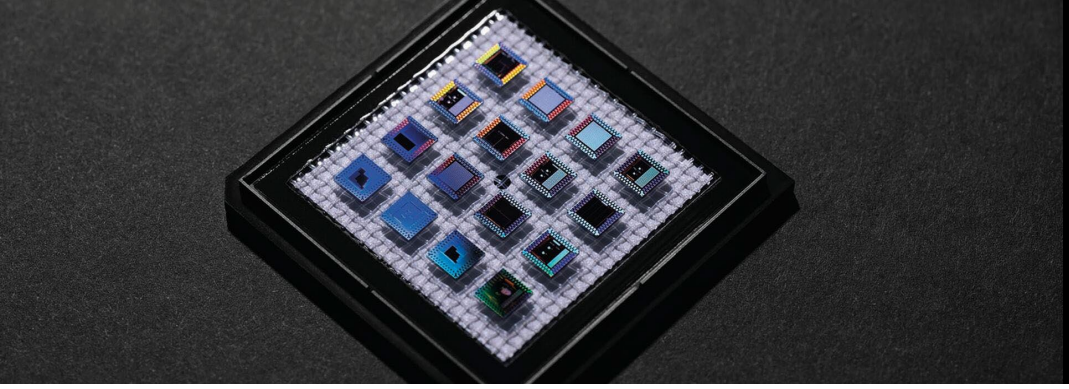


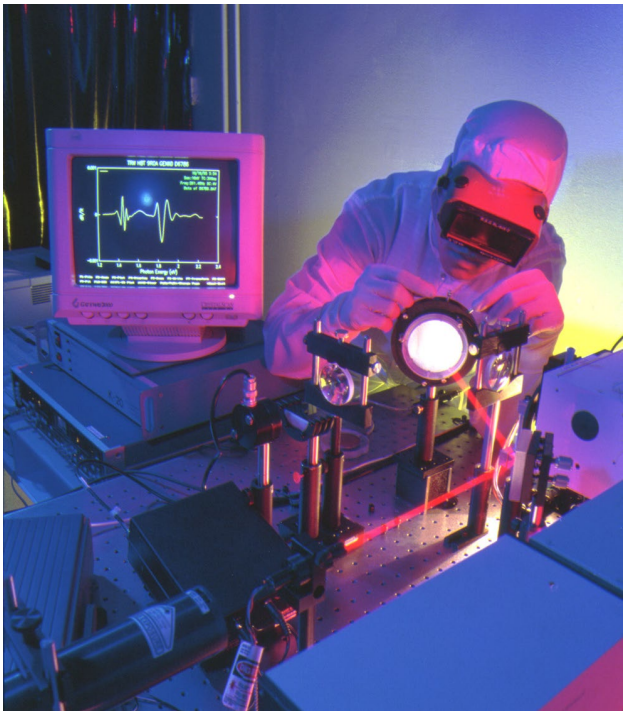
Thin Film Growth & Characterization

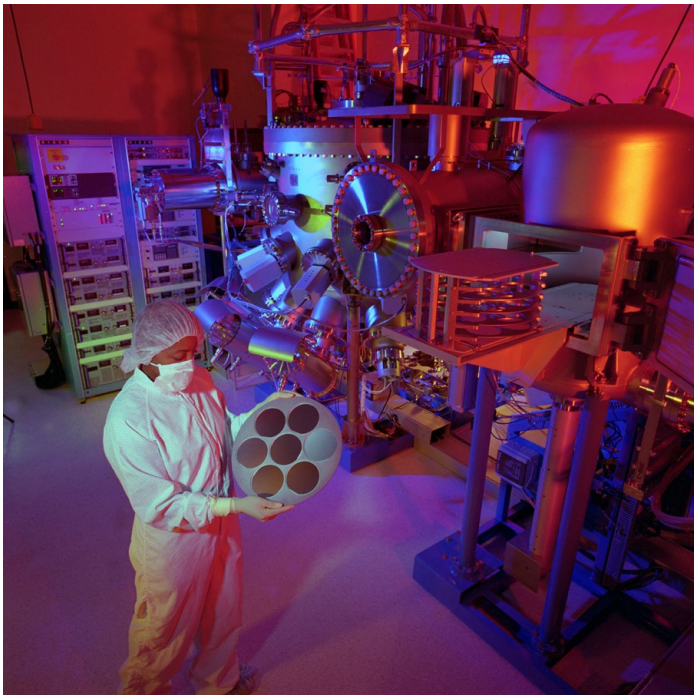
OVERVIEW

The Semiconductor Materials Department has extensive experience in the molecular beam epitaxial (MBE) growth of III-V semiconductors for applications requiring high-performance monolithic microwave and millimeter-wave integrated circuits. Our comprehensive in-house characterization capabilities enable us to rigorously test our materials to ensure they meet the exacting standards required for critical applications.

MATERIALS DEVELOPMENT

In addition to our established production processes, we are always looking to further advance the fields of materials science and thin film growth by collaborating with customers to develop state-of-the-art solutions to meet their unique requirements





SERVICES OFFERED

- MBE growth of custom multi-layer stacks of As, P, and N-based III-V materials (see following pages for details)
- Engage with customers to explore solutions to unique technological challenges, leveraging our extensive knowledge of epitaxial growth and materials science
- Characterization of customer supplied epi-materials in collaboration with our characterization engineers.

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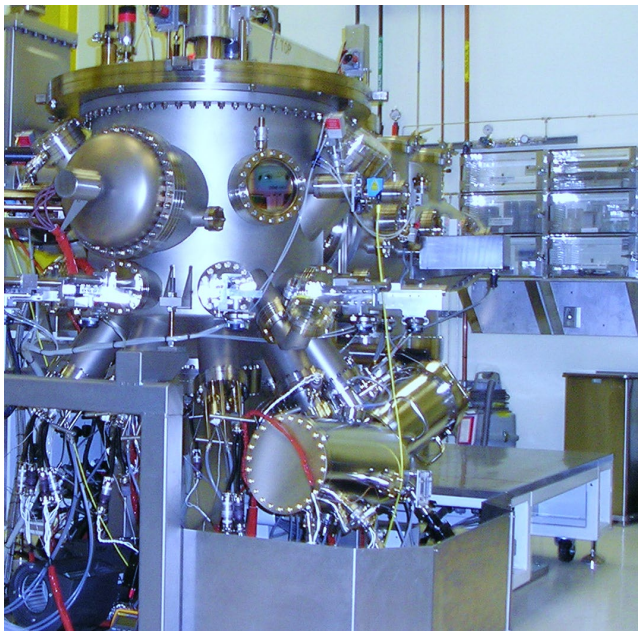
Molecular Beam Epitaxy Growth

Arsenide, Phosphide, or Nitride-based III-V Materials



Production-scale Epitaxial Growth

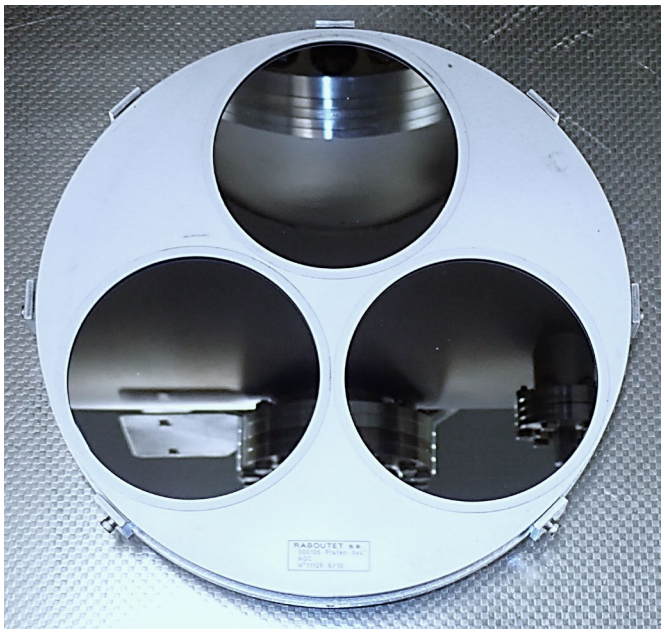
- Production on GaAs and InP wafers
  - Redundant MBEs enable growth on one during periodic maintenance on the other for maximum production uptime
- GaAs/InP-based materials (n or p-type):
  - GaAs/InP (insulating or conductive layers)
  - InGaAs/InAs (high mobility channels)
  - AlGaAs/InAlAs (barrier layers)
- Nitride-based materials available for on-request technology development:
  - GaN/AlN
  - InGaN/AlGaN
  - Si-doping available
- Elemental MBE sources:
  - In, Ga, Al (Group III elements)
  - As, P, N (Group V elements)
  - Si, Be (Group IV and II elements for n and p-type doping)
- Layer thicknesses can range between several microns and several angstroms – only 2% non-uniformity

Experience with Epitaxial Structures for High-Performance Applications

- Gallium Arsenide HEMTs
  - High and medium power amplifiers
  - High linearity
- Indium Phosphide HEMTs
  - Ultra-high channel mobility
  - Low noise and high frequency amplification
- Indium Phosphide HBTs
  - High speed digital circuitry
  - Mixed signal

Growth on a Variety of Wafer Sizes

- Multiple wafers can be loaded during each MBE Run depending on wafer size
  - 5 x 3-inch wafers
  - 3 x 4-inch wafers
  - 1 x 6-inch wafer
  - 1 x 8-inch wafer
  - 1 x 12-inch wafer



Example of platen: 3 x 4-inch GaAs wafers

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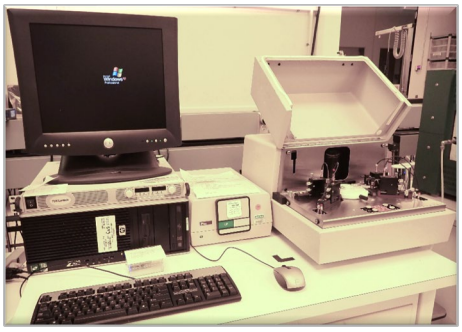
Materials Characterization
Electrical & Optoelectrical

Mobility Mapper

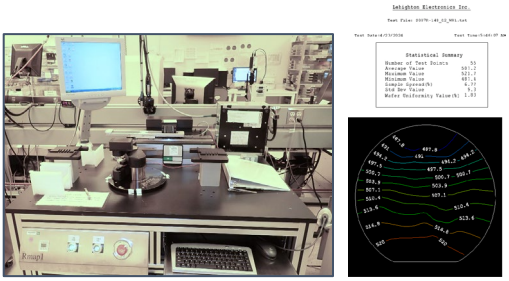
- Measures sheet resistance, mobility, & carrier concentration via RF reflectance
- Wafer size: 1.2" to 4" diameter

Hall System



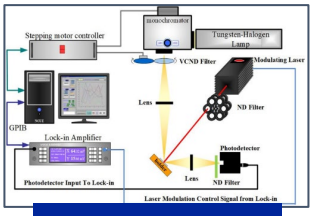
- Measures sheet resistance, mobility, & carrier concentration via Van der Pauw method
- Sample size; 1 sq cm
- Destructive technique

Sheet Resistance Mapper



- Measures sheet resistance via non-contact inductive probe
- Automated mapping of sample area
- Wafer size: 2" to 6" diameter
- Max sample thickness: 800 µm

Photoreflectance System

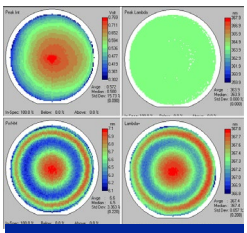


Photoreflectance (PR) Schematic

- Measures photo-reflectance of optoelectronic materials
- Change in reflectance of probe beam measured vs probe wavelength
- Reflectance change is largest near band gap of sample layers

Photoluminescence Mapper

RPM 2000



PL Map – GaN Epi

- Room temperature photoluminescence (PL) mapping of optoelectronic materials
  - UV / Vis (300 nm – 1000 nm)
  - IR (900 nm – 2000 nm)
- Epi thickness mapping via interferometry (Vis only)
- Wafer size: 2" to 6" diameter
- Low temp (9K – 300K) PL on 1 sq cm samples

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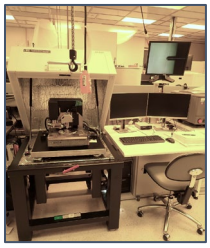
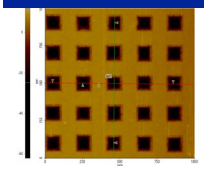
Materials Characterization

Surface & Structural Analysis

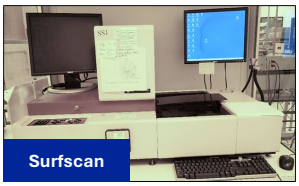
Atomic Force Microscopy





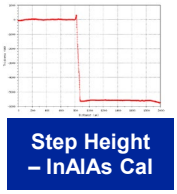
- Measures surface topography of epi, substrates
- Wafer size: 1" to 8"
- Max thickness: 12 mm

Defect Mapping



- Measures particle/defect size, density via laser scattering (films, substrates)
- Wafer sizes: 2", 3" 4", 6", 8"
- Catalogs particles/defects via reflected, scattered, and refracted light signals

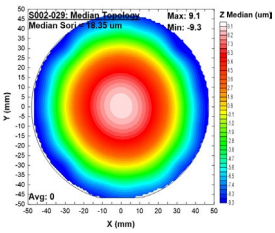
Dektak



- Measures 1D step height, depth
- Extracts epi thickness, 1D surface roughness
- Wafer size: 2" to 8"
- Max thickness: 45 mm

UV Microscope

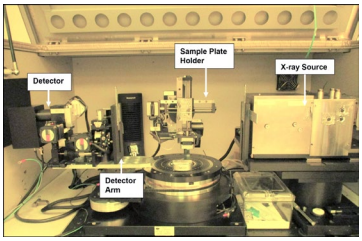
Wafer Shape

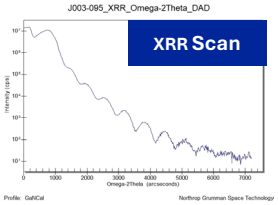


Median Warp Map

- Measures wafer thickness, bow, & warp
- Non-contact, automated mapping
- Wafer size; 2" to 6"
- Minimum thickness: 120 µm
- Max thickness: 10 mm

X-ray Diffraction





- Extracts epi composition, thickness, crystal quality, relaxation
- Automated mapping of wafer area
- Wafer size: 2" to 6"
- Min sample size: 1 sq cm
- Max sample thickness: 1 mm
- Probe area: 1mm x 10 mm

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