In-line Process and Equipment Performance Monitoring using Site Flatness and Raman Mapping

Characterization of Process Footprints

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Topics To Be Discussed

- Necessity of In-Line Monitoring
  - Process Performance (Uniformity & Repeatability)
  - Equipment Performance (Up Time & Reliability)
- Conventional Process Monitoring Values
  - RTO: Oxide Thickness and Uniformity
  - Implant Anneal: Sheet Resistance & SIMS Profiles
  - Silicides: Sheet Resistance
  - Etching: Etch Rate & Profiles
  - CVD: Film Thickness, Dep. Rate, n, k, etc.
- Systems Used in This Study
  - SRTF-302LP: Hot Wall RTP
  - OSP-300: Optical Surface Profilometry
  - MRS-300: Multi-wavelength Raman Spectroscopy
- New Metrology Tools for Hidden Variations
  - Pattern Effect (Blanket Wafer vs. Patterned Wafer)
  - Process Pattern Shift or Drift
  - Global & Local Deformation or Distortion (Elastic vs. Plastic)
  - Bow, Warpage, Site Flatness, Stress, Strain etc.

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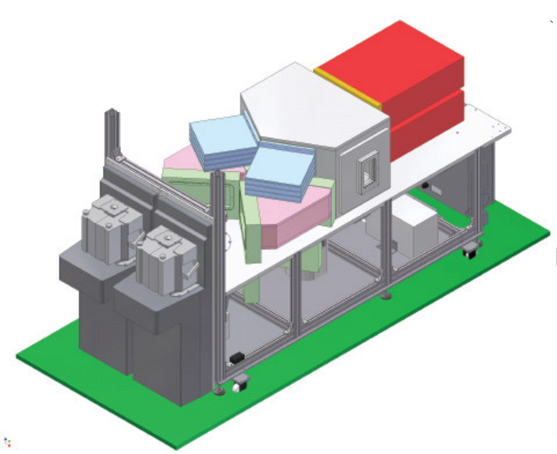
Process & Metrology Systems Used in This Study

SRTF-302LP

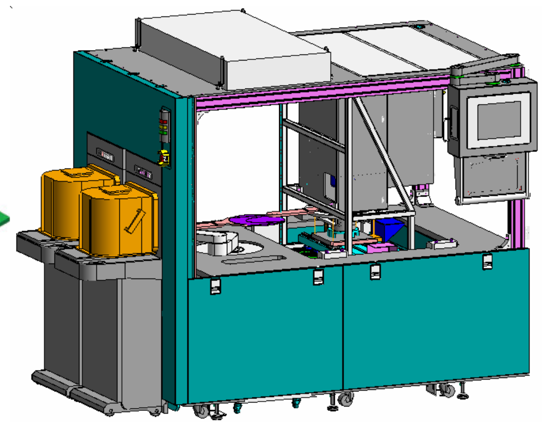


Single Wafer
Rapid Thermal Furnace

RTA under O_2 Controlled Environment (100°C~1100°C)

- Dual Chamber Configuration
- No Lamps
- Low Maintenance
- High Repeatability
- High Stability
- Small Footprint
- Low Power Consumption
- Self Contained System
- No Other Facility Required

OSP-300

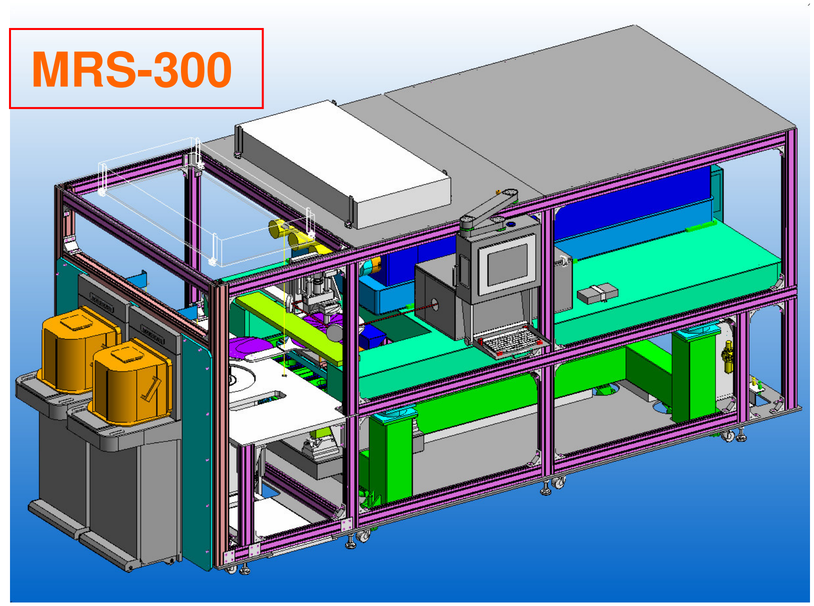


Optical Surface Profilometry

Non-destructive Metrology Tool for Blanket and Patterned Wafers

- Global Wafer Warpage
- Global Wafer Distortion
- Global Wafer Stress
- Local or Site Flatness
- Wafer Curvature along Crystal Axes
- Pattern Overlay
- Small Foot Print
- Minimum Facility Requirement

MRS-300



Multi-wavelength Raman Spectroscopy

Non-destructive Localized Lattice Stress & Strain Evaluation Tool

- Very High Wavelength Resolution
- Three Wavelengths: 457.9, 488.0 & 514.5nm
- Three CCD Cameras
- Impact of Process Steps on Stress & Strain
- No Moving Parts in Spectroscope
- Auto Focus Microscope
- WaferMasters' Proprietary Design

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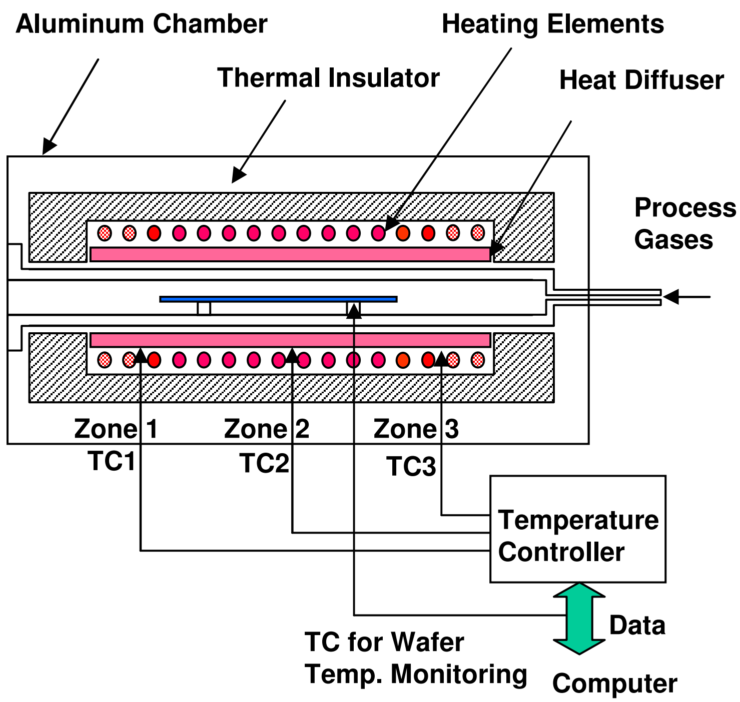
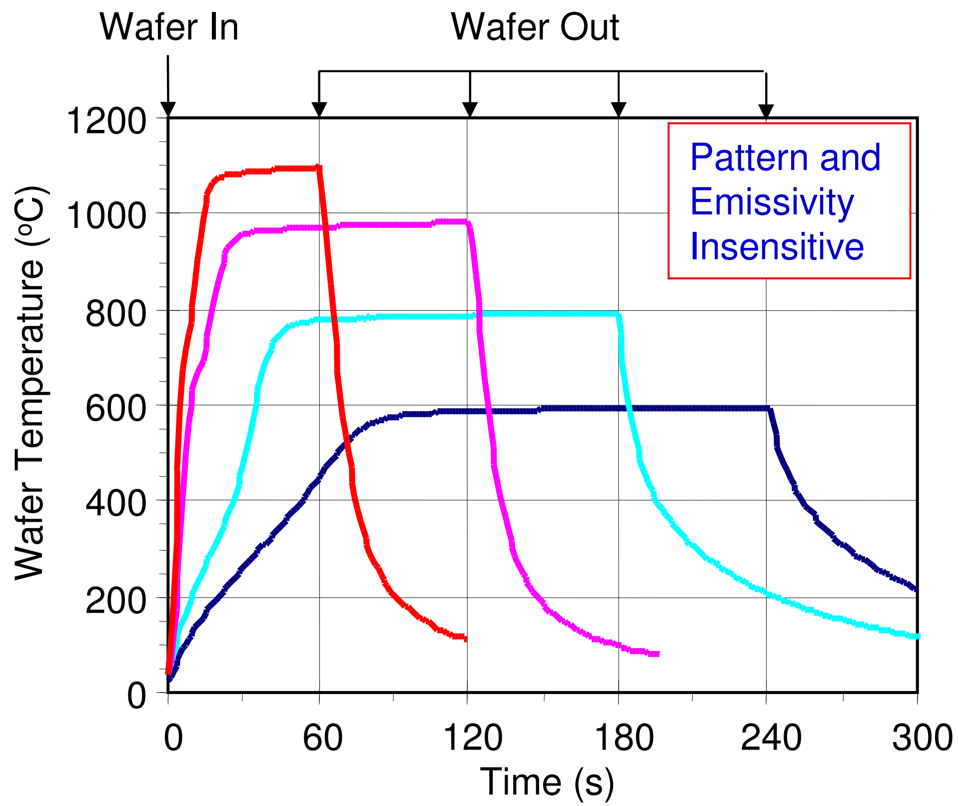
Isothermal Process Chamber and Wafer Temperature Profiles

SRTF-302LP





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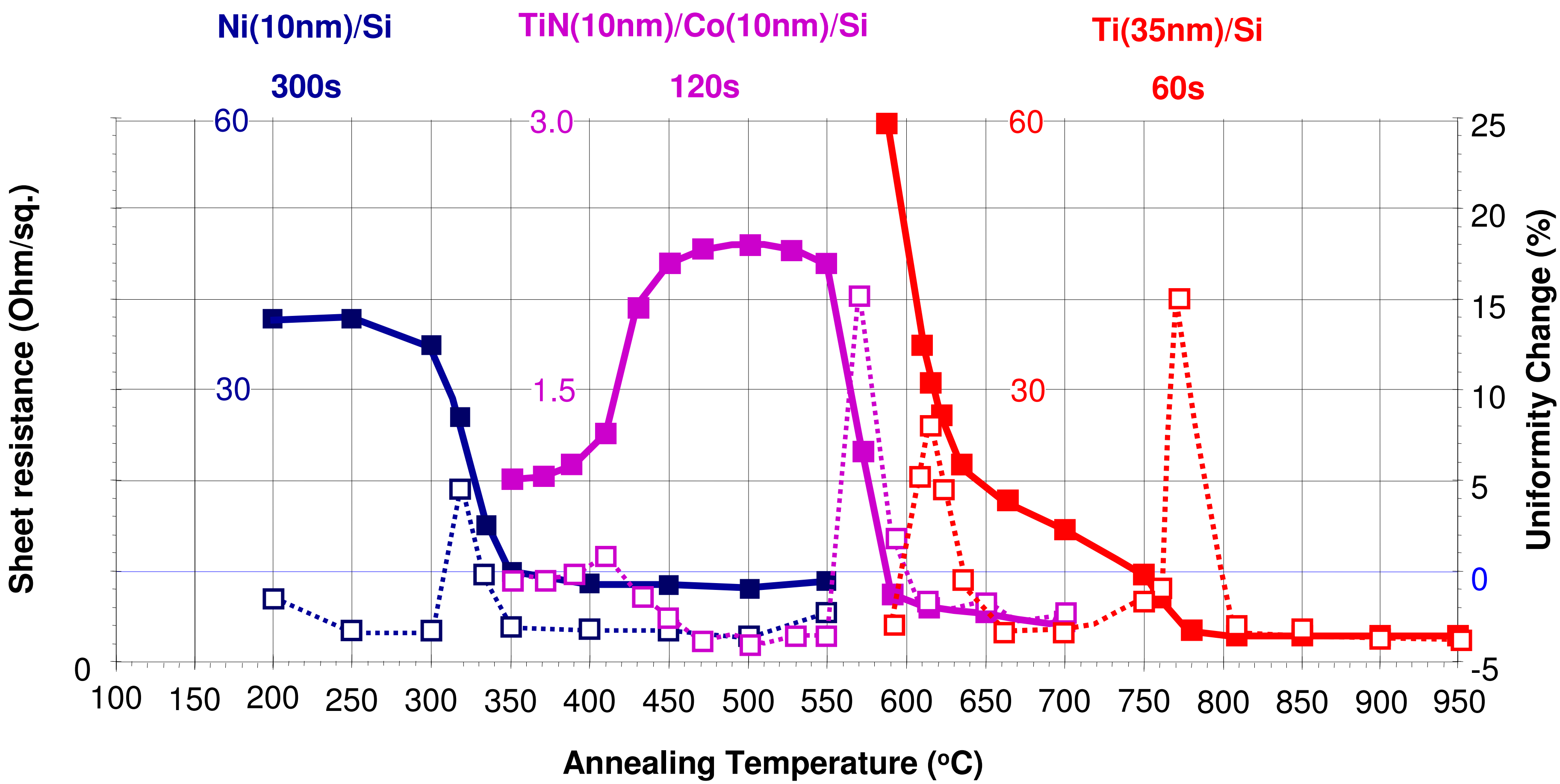
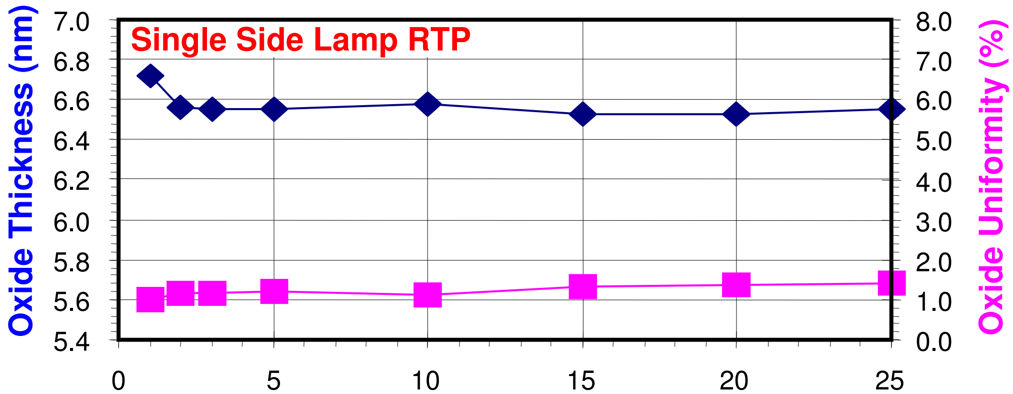
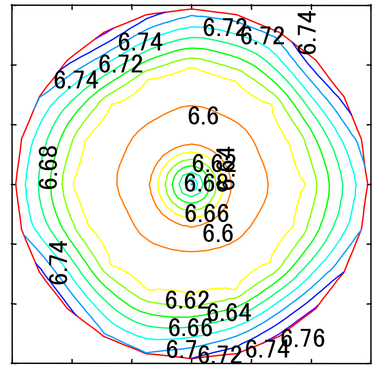
Temperature Sensitivity of Sheet Resistance of Various Silicides

Process Capability of SRTF-302LP

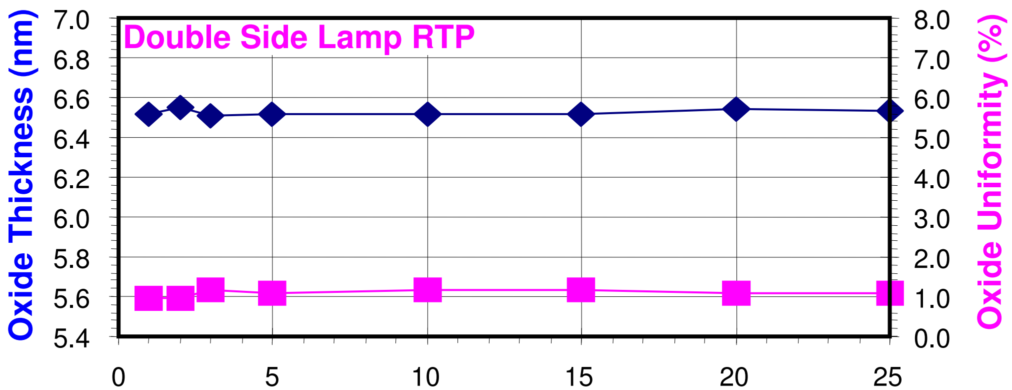


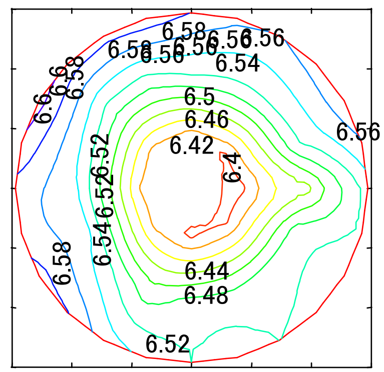
RTO Repeatability: RTP System Dependence



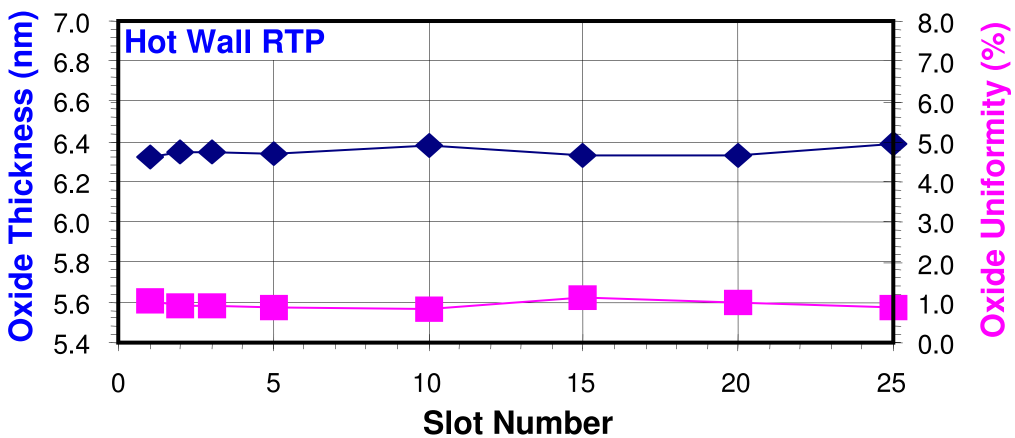


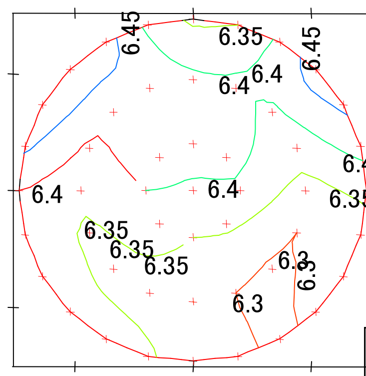
Single Side Lamp RTP





Double Side Lamp RTP





Hot Wall RTP

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Strategy for Manufacturing Process and Quality Improvement

In-Line Process and Equipment Performance Monitoring

Improvement of Measurement Accuracy & Resolution?

System Enhancement

Changes in Wafer Surface Profile:
Bow, Warpage, Distortion, Flatness

Optical Surface Profilometry

Stress Distribution near Interface:
Stress, Crystallinity, Strain, Composition

Multi-Wavelength Raman Scattering

1. **Detect Subtle Differences between Processed Materials**
2. **Detect and Quantify Process Effect**
   - **Uniformity, Repeatability, Distribution**
3. **Utilize Collected Information as Process and Equipment Monitoring and Control Feedback**

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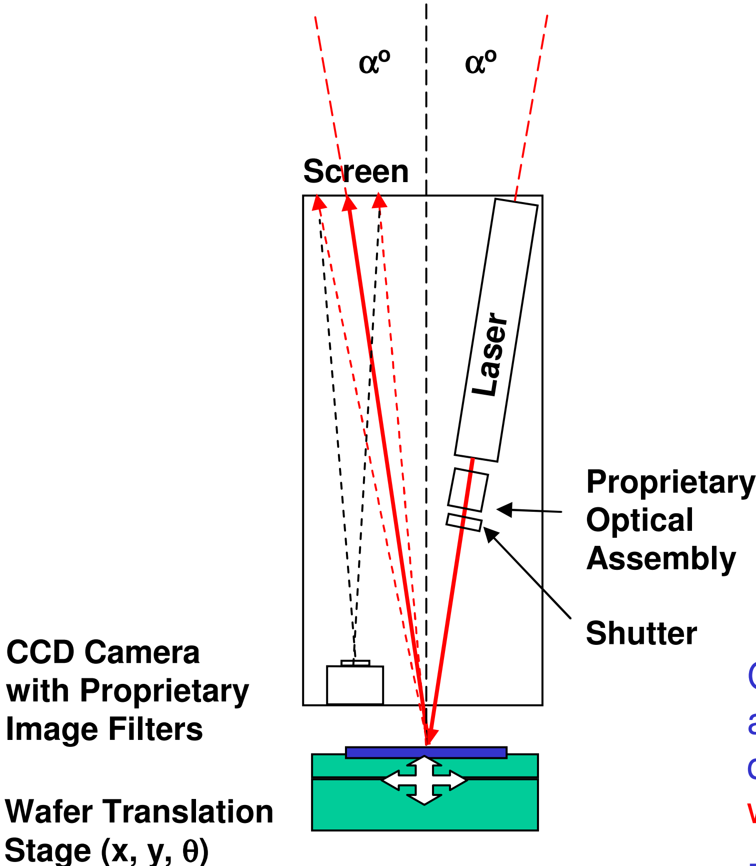
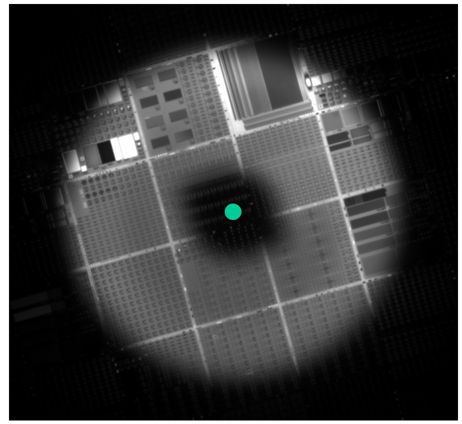
OSP-300: Operating Principles

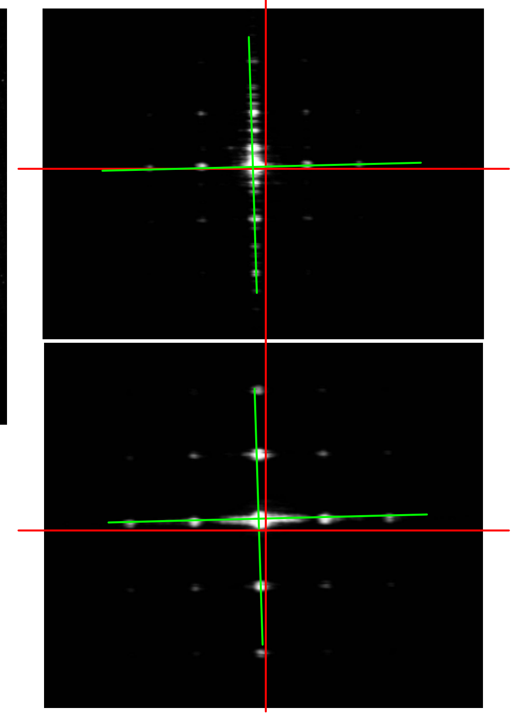
Angle of Reflection = Angle of Incidence
(zero order diffraction)



Measurement Spot



Processed Images



Reflection Image
Scattering Image
Diffraction Image
Image Movement
Image Twist
Image Distortion

Captured images (reflected, diffracted and scattered images) are transformed into proprietary data set and analyzed to quantify global and local wafer distortion, stress and warpage.

Beam size: ~0.7mmϕ

Image resolution: ~1arcsec (1/3600 arcdeg, or 4.85µrad)

Stage resolution: ~0.5µm

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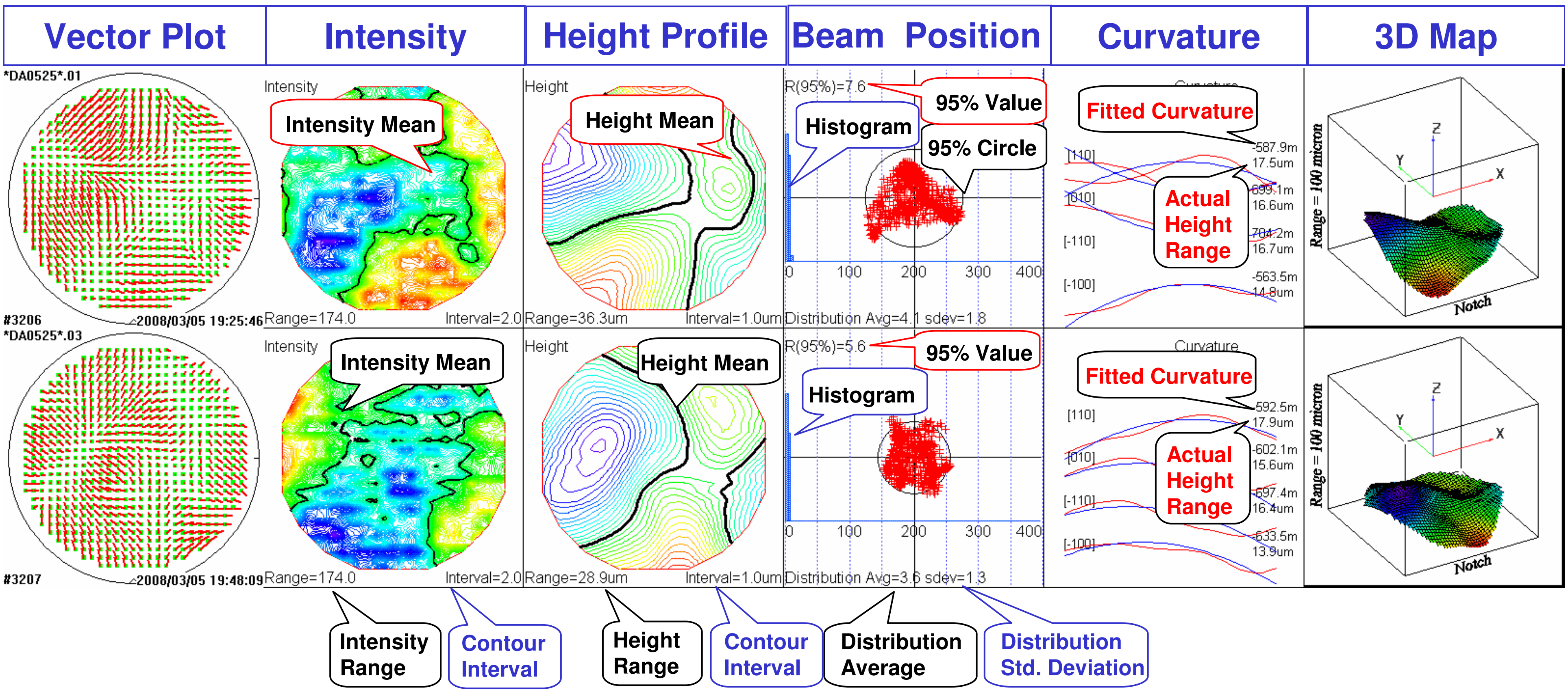
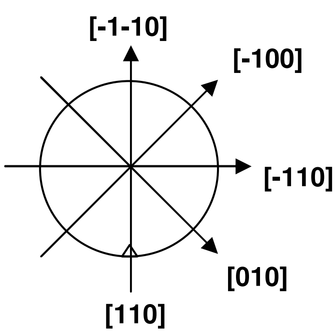
OSP-300: Measurement Data Display





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OSP-300: Wafer Curvature Estimation

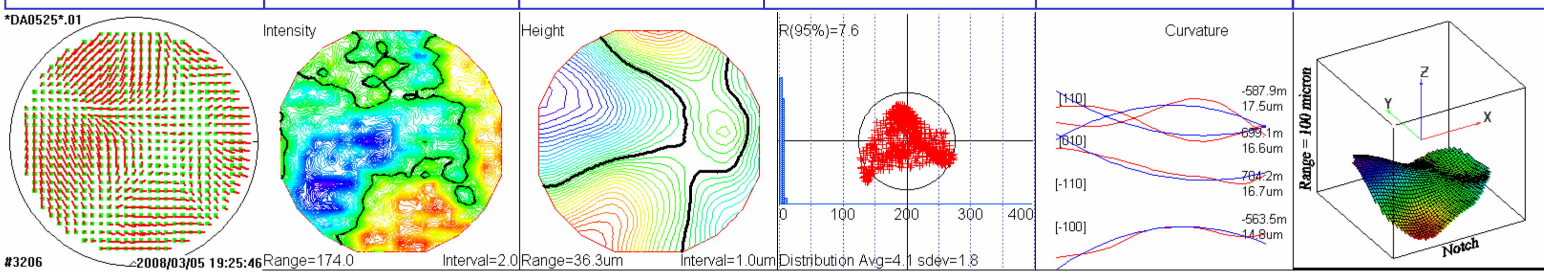
Measurement Parameters

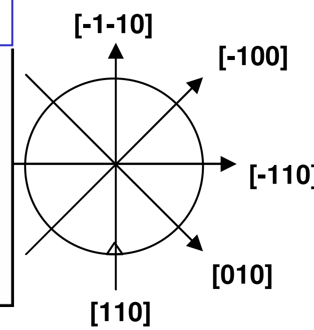
- Surface Profile
- Curvature
- Warpage
- Site Flatness
- Distortion
- Stress/Strain
- Process Effect
- Pattern Overlay

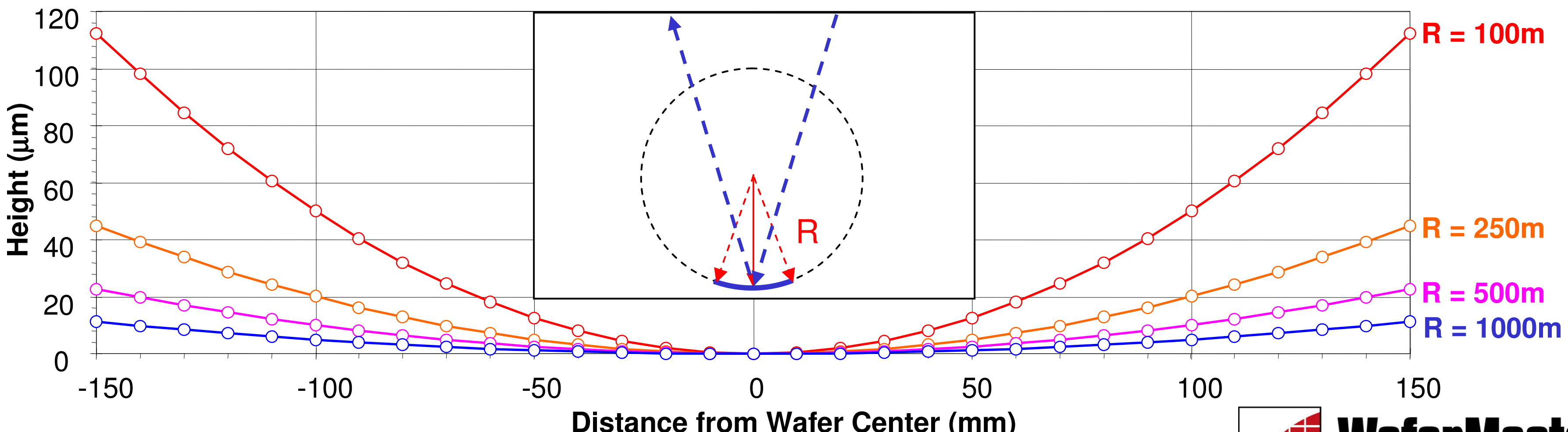
Measurement Capability

- Blanket Wafers
- Device Wafers
- SOI Wafers
- Bonded Wafers
- Quartz Wafers
- Glass Wafers
- Sapphire Wafers
- Unpolished Wafers

Vector Plot	Intensity	Height Profile	Beam Position	Curvature	3D Map







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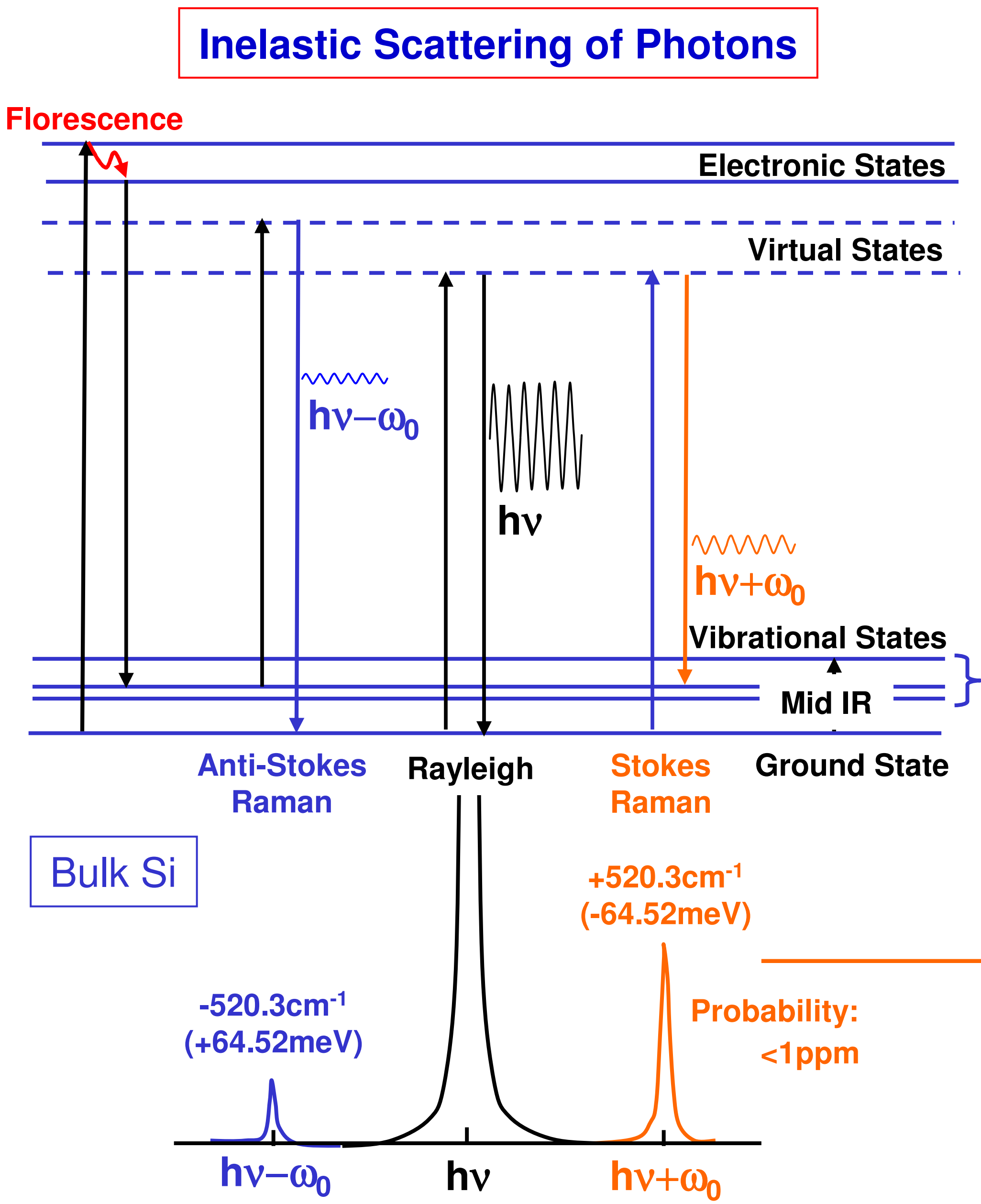
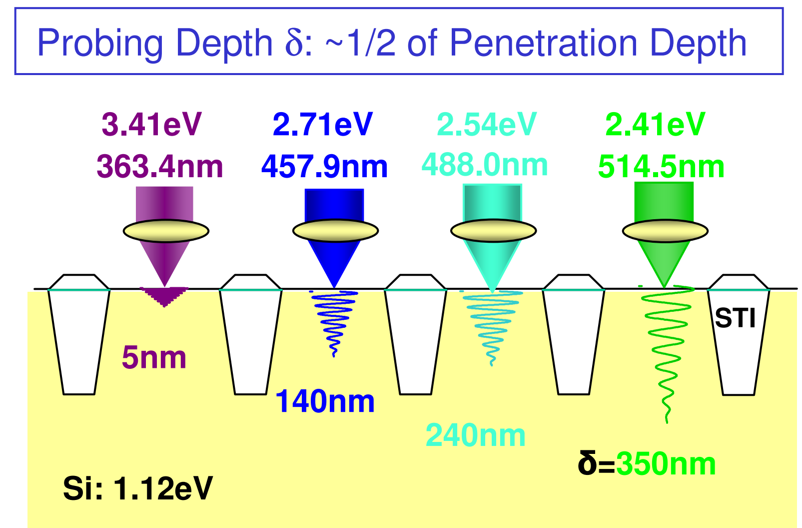
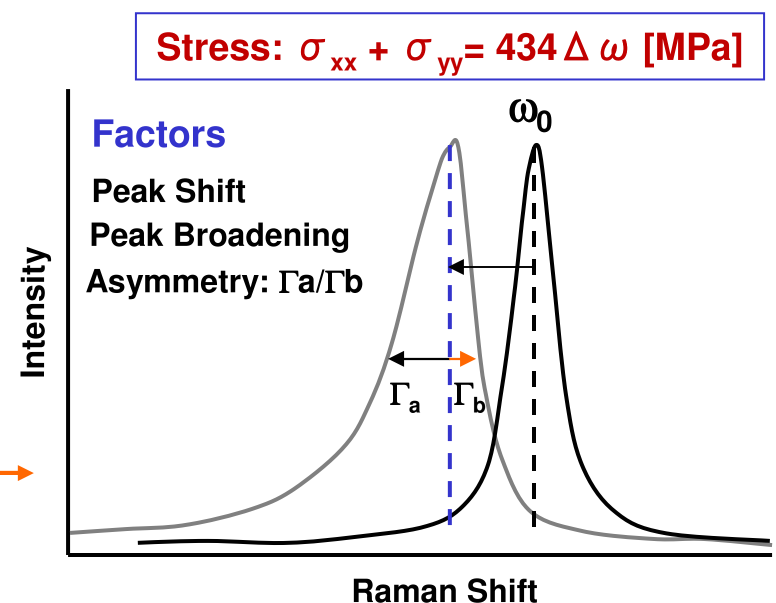
Raman Scattering: Lattice Stress & Strain Characterization







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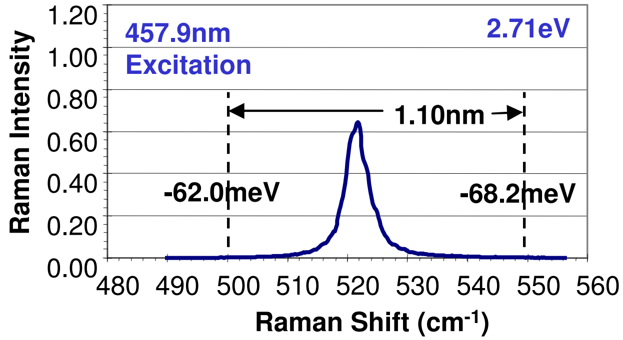
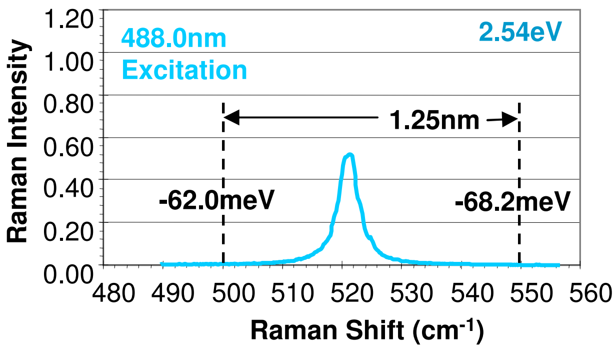
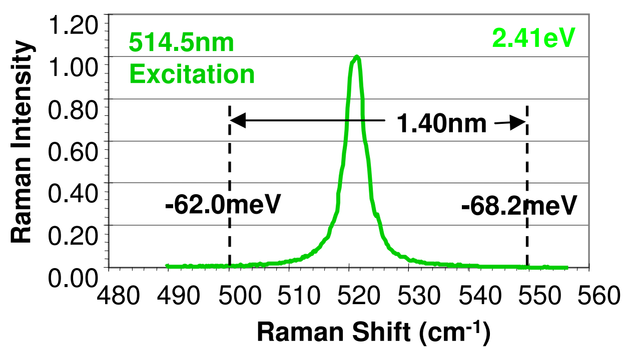
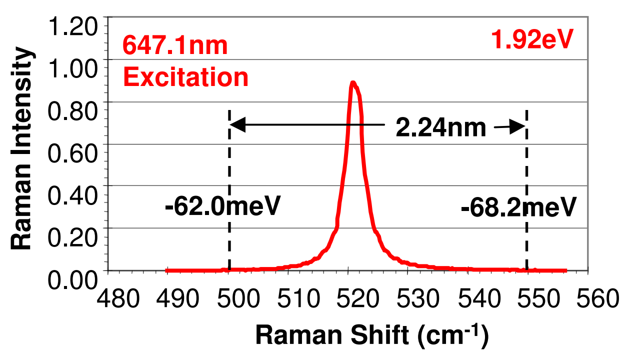
Raman and Photoluminescence Signals from Bulk Si

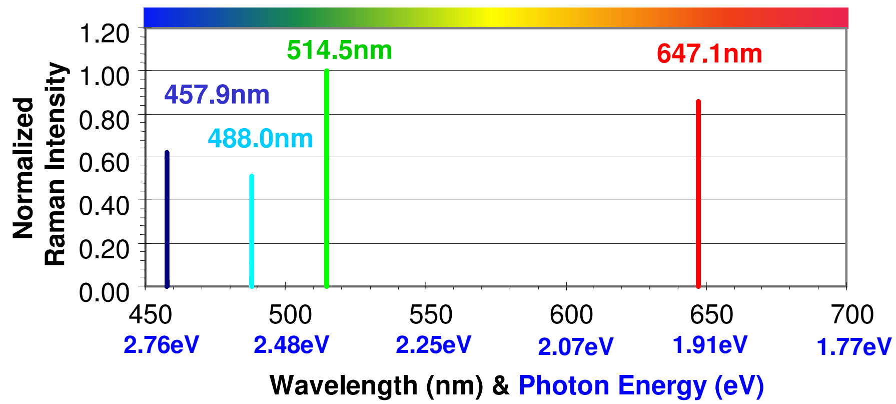




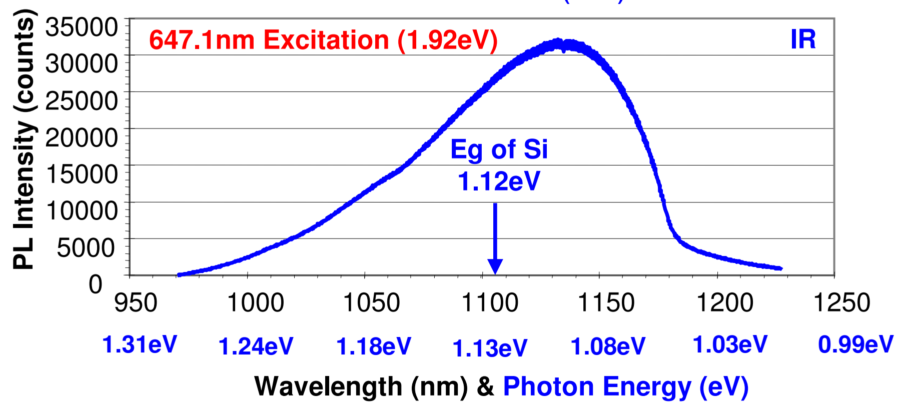




Raman Signals from Si



Photoluminescence (PL) from Si



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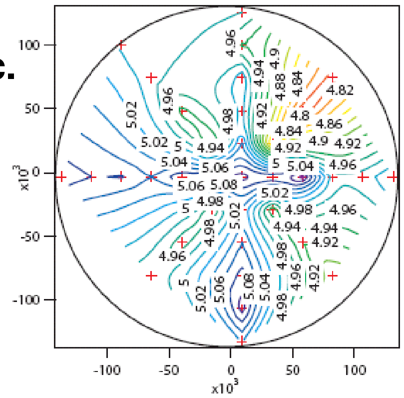
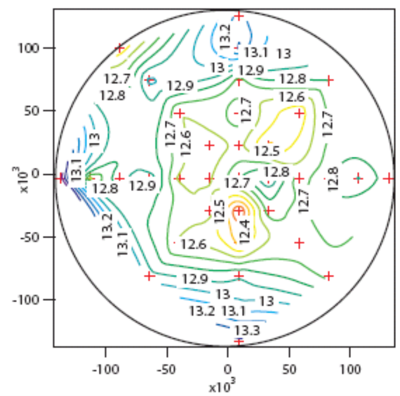
Ge Concentration Maps from Strained Si

Nominal Ge Conc.

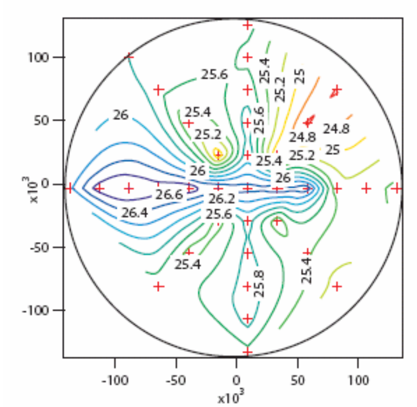
5%

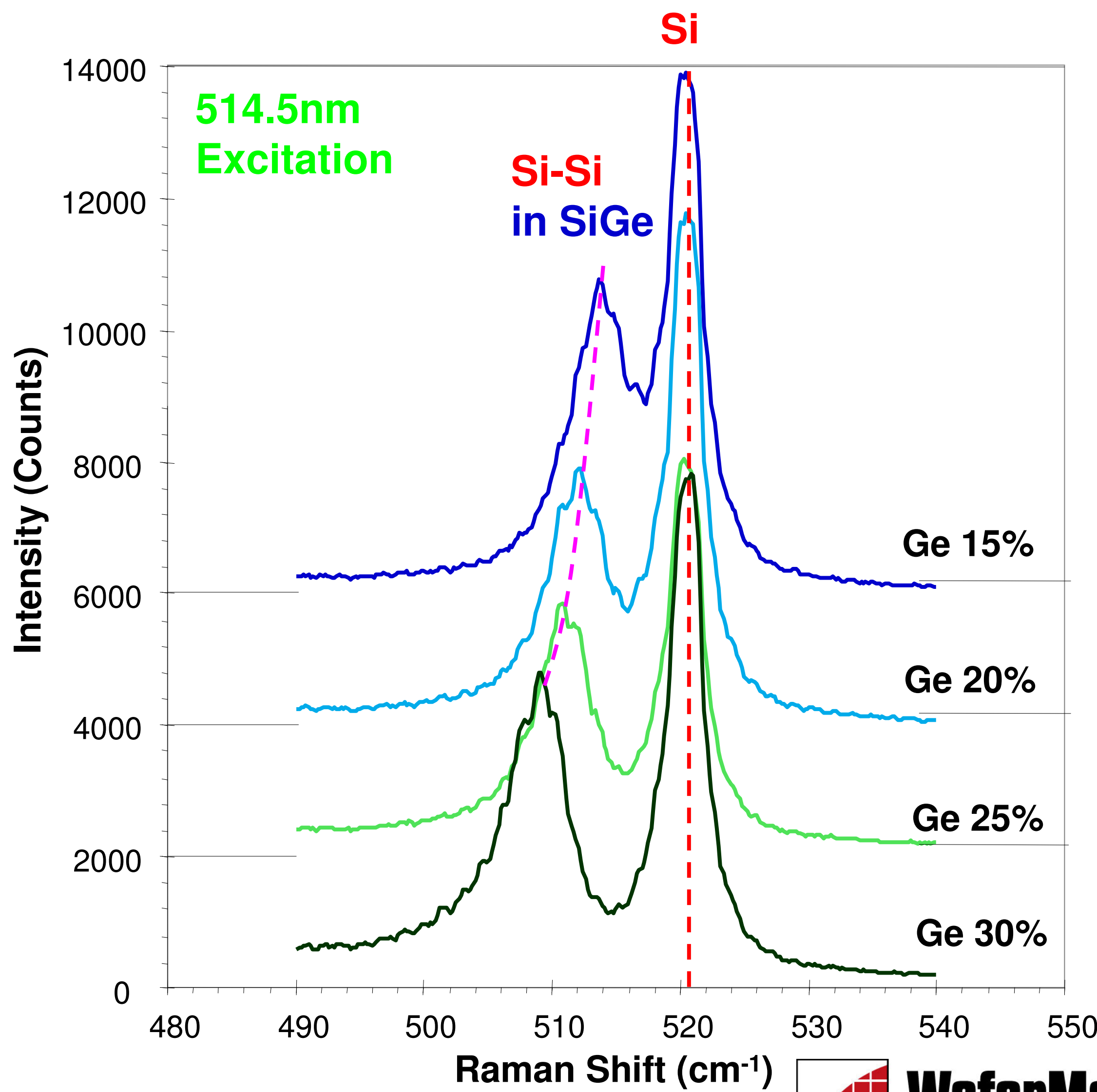


15%



25%





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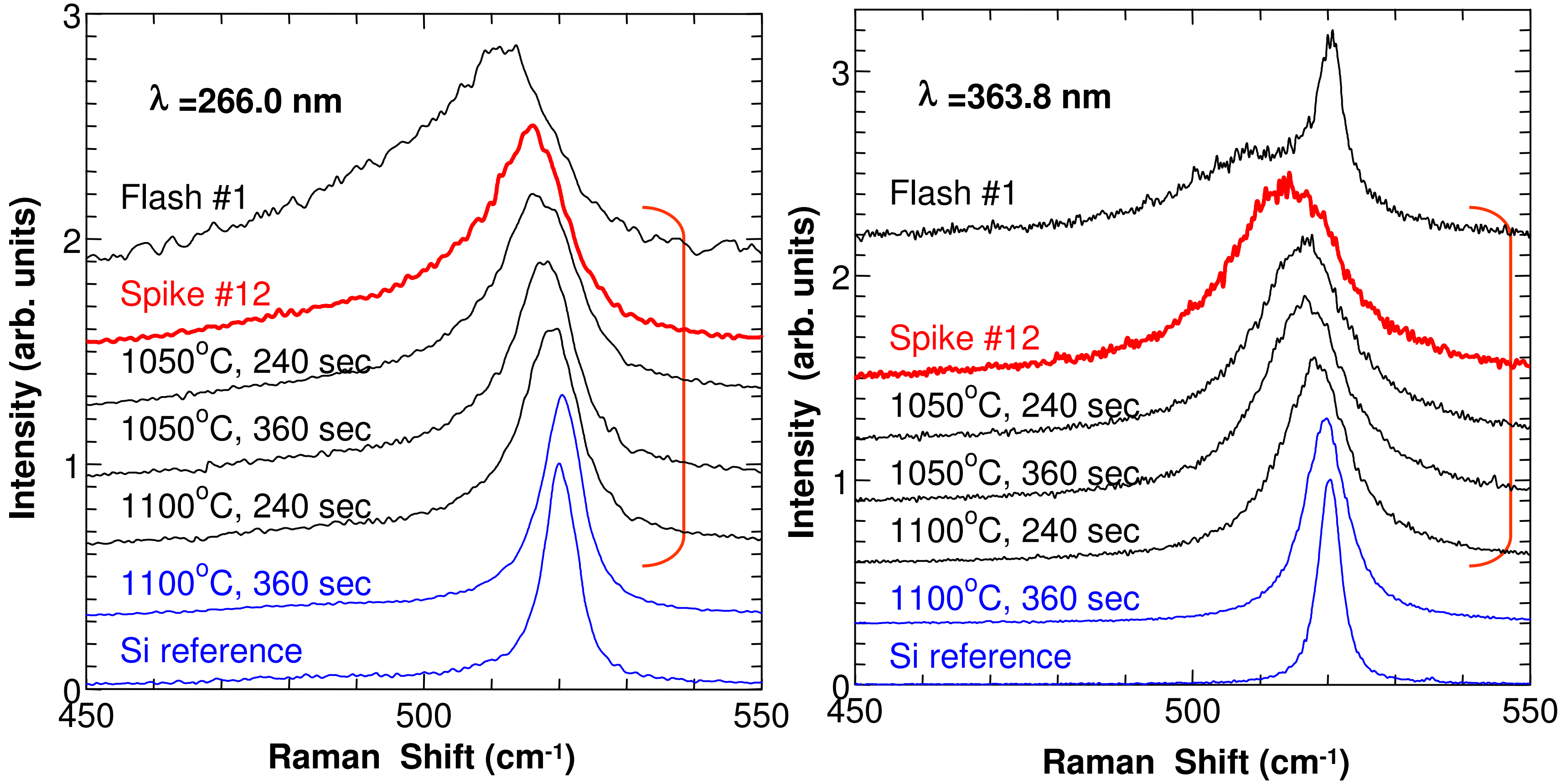
Raman Characterization: Implant Damages

B : 1keV, 1x10^{15} cm^{-2}
Ge PAI: 5keV, 1x10^{15} cm^{-2}



Asymmetrical broadening with a peak shift to a smaller wavenumber
⇒deficient recrystallization & poor damage recovery

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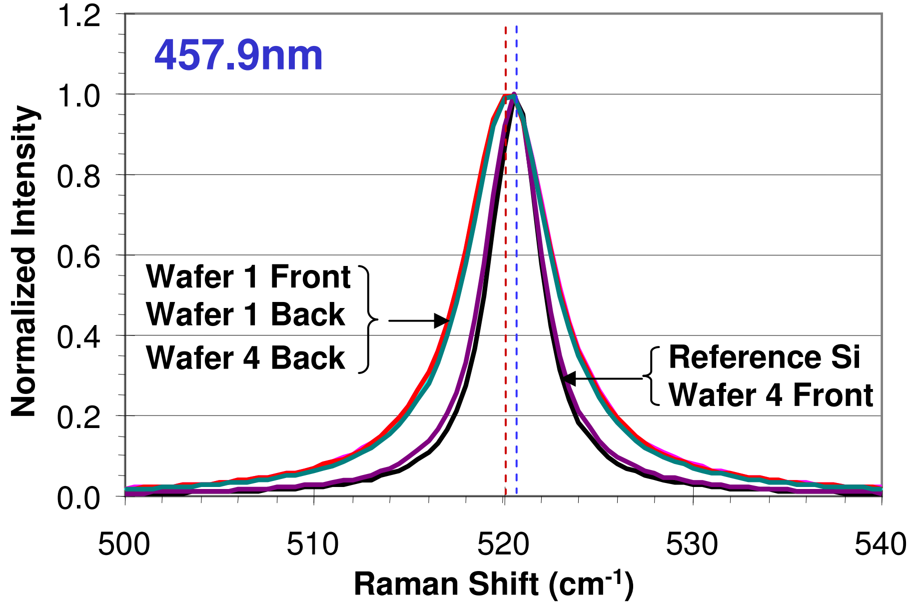
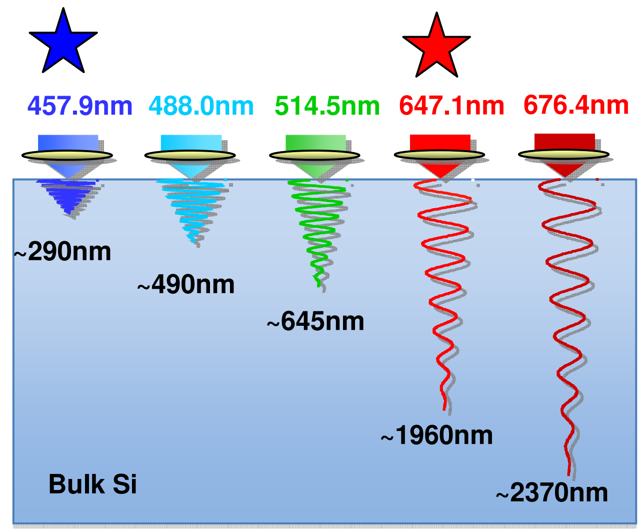
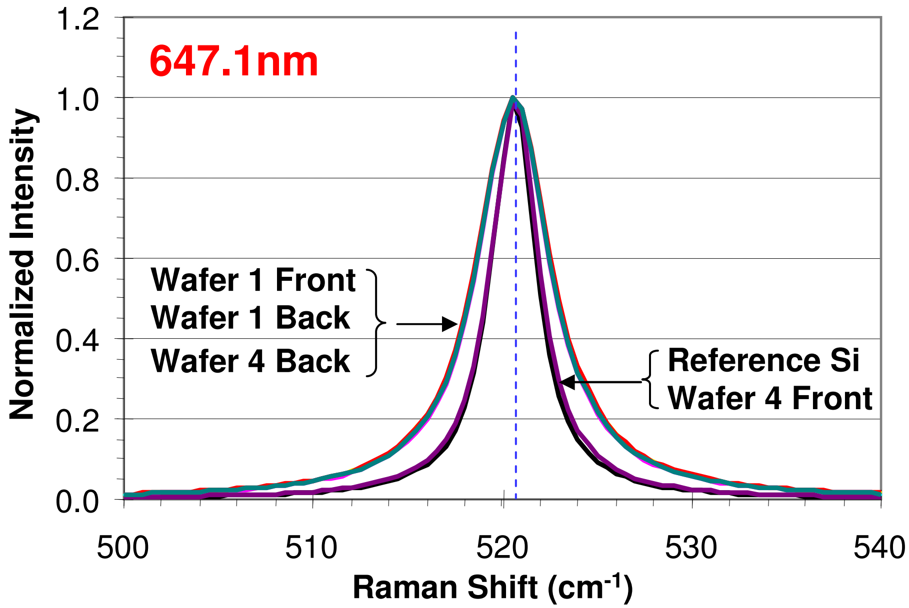
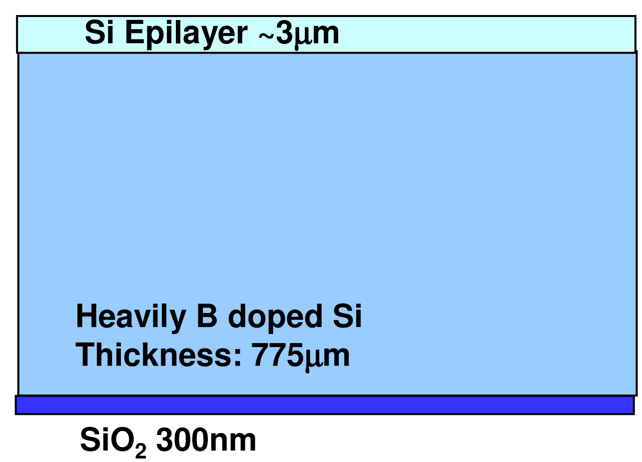
Raman Characterization: Epilayer Quality









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OSP-300 & MRS-300 Application Examples

RTO Film Characterization

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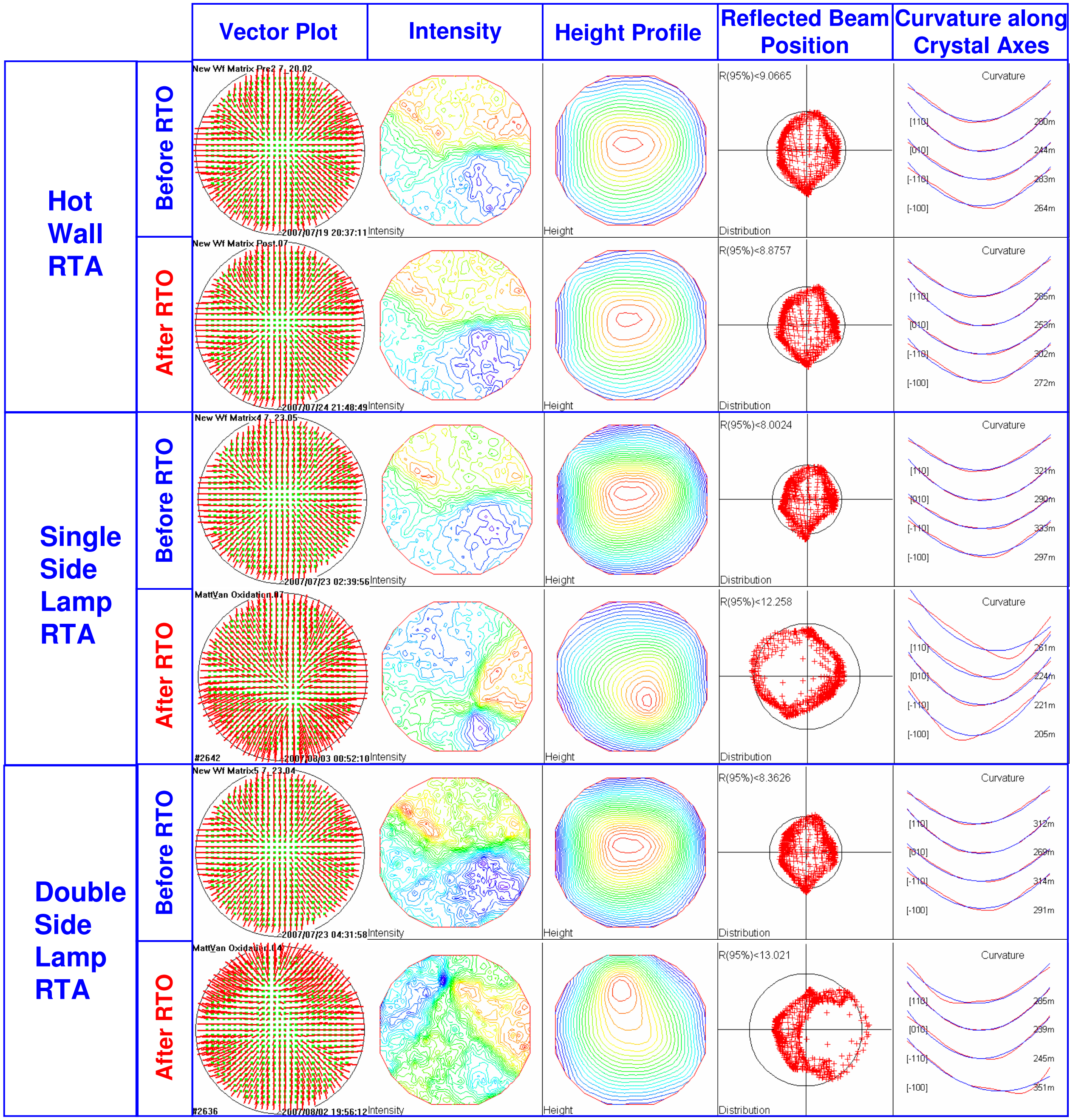
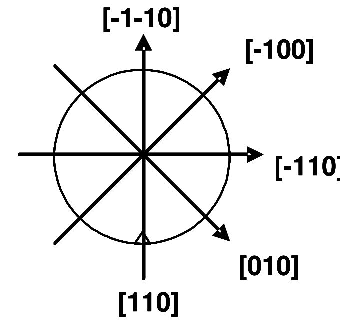
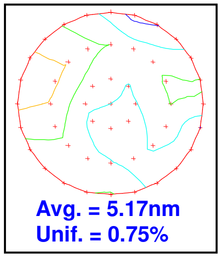
Site Flatness before and after RTO

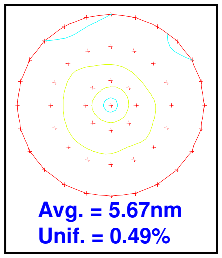


1030°C

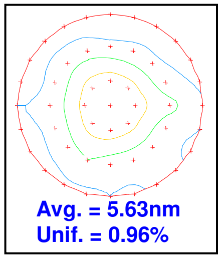




No Change



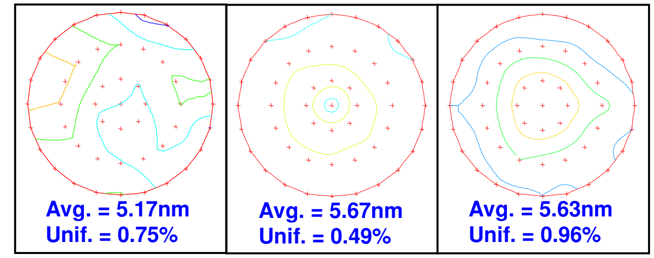
Distortion

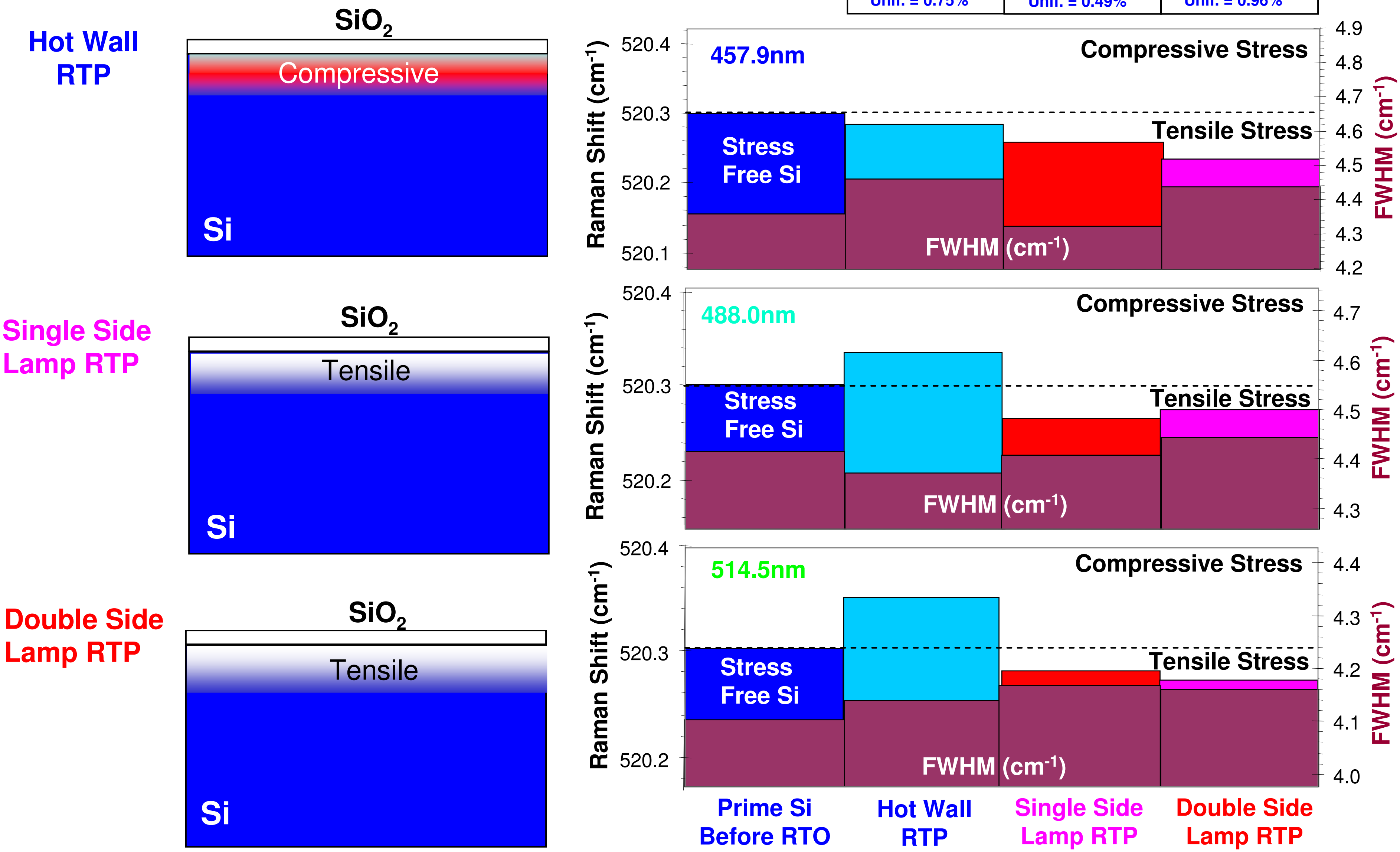


Distortion

Si Stress Change after RTO at 1030°C

RTP System Dependence

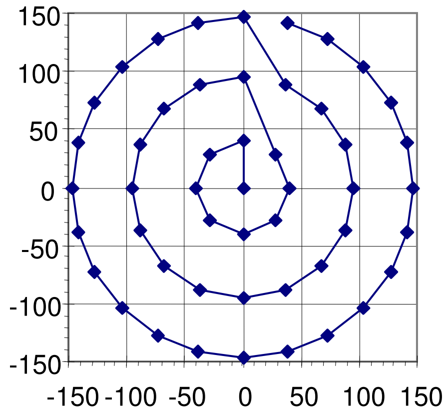


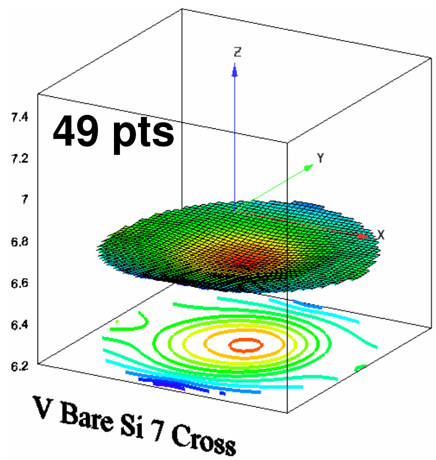


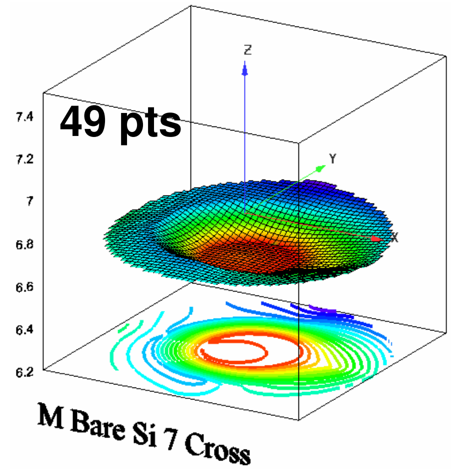
Effect of Lateral Resolution or Measurement Points

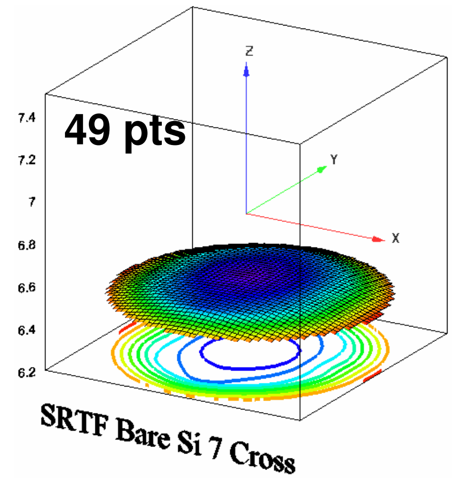
Reality of RTO Process Uniformity

49 points







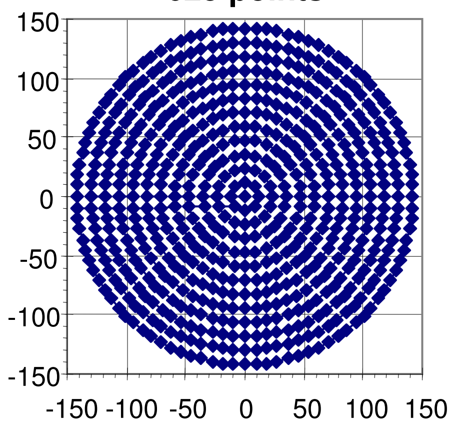


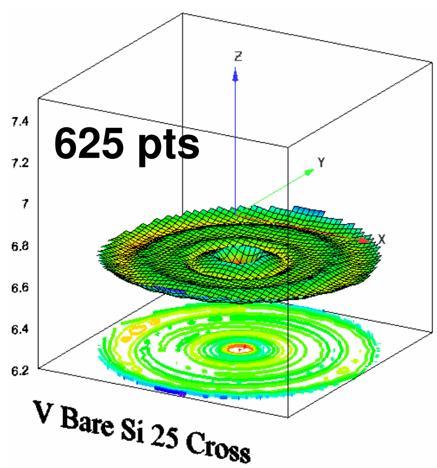
Single Side Lamp RTP

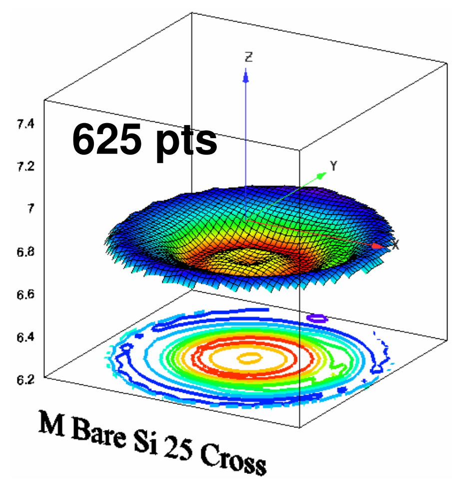
Double Side Lamp RTP

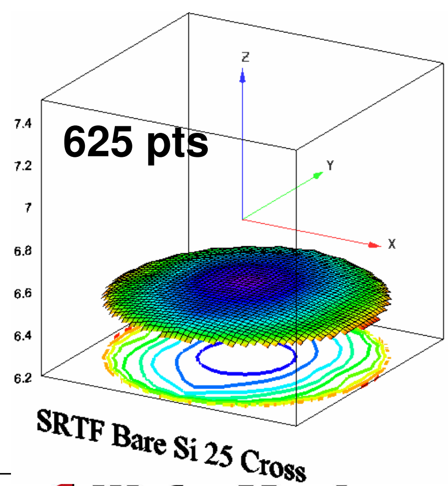
Hot Wall RTP

625 points









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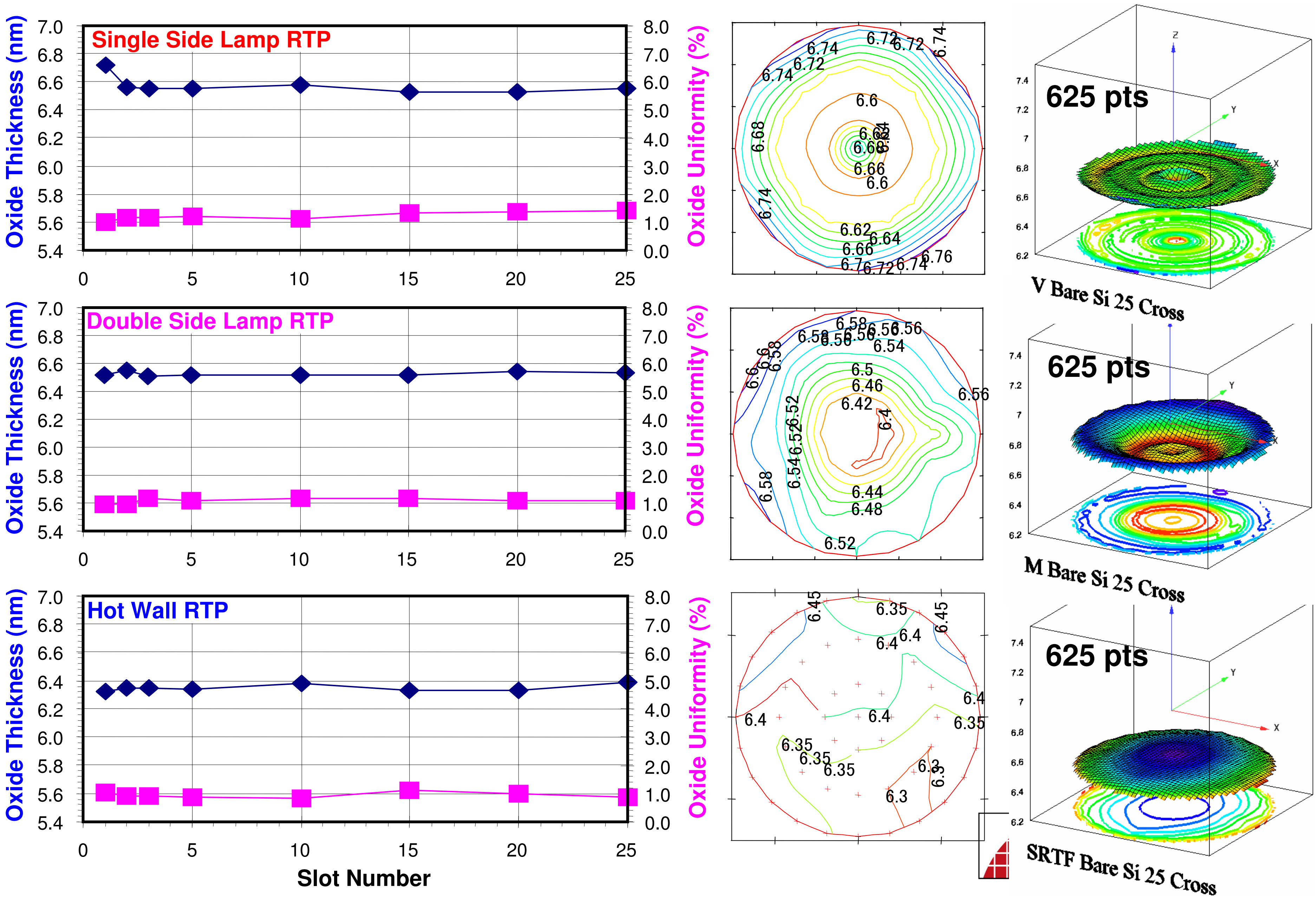
RTO Repeatability: RTP System Dependence



Summary

- Introduced Two New Metrology Tools and Their In-Line Process and Equipment Monitoring Applications
- Demonstrated Process Footprint Measurement Sensitivity and Capability of New Metrology Systems
- Proposed New Applications with In Line Monitoring Implementation Examples in Mass Production Environment

Due to the confidentiality agreement with customers, I can only share very limited information at this time.

Product Demos are Welcome.

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