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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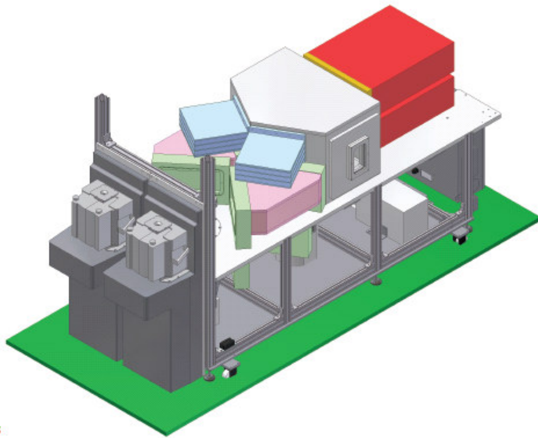
Process & Metrology Systems Used in This Study

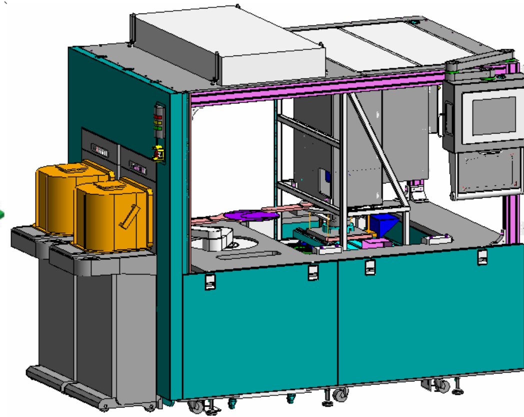
SRTF-302LP



Single Wafer
Rapid Thermal Furnace
RTA under O_2 Controlled Environment (100ºC~1100ºC)

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

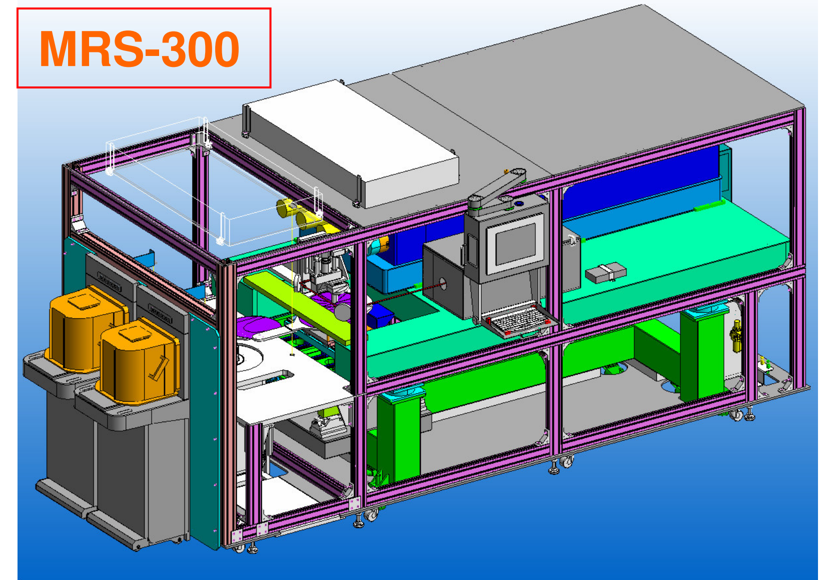
OSP-300



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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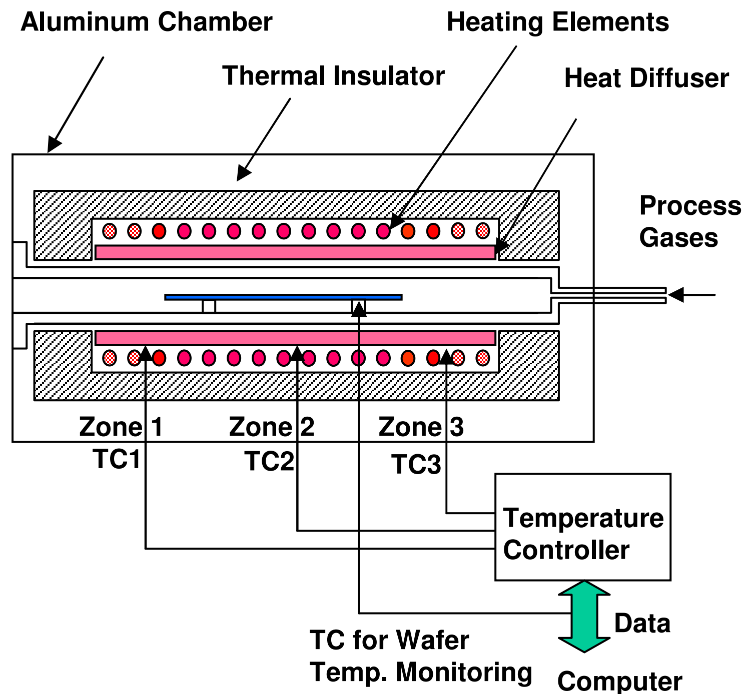
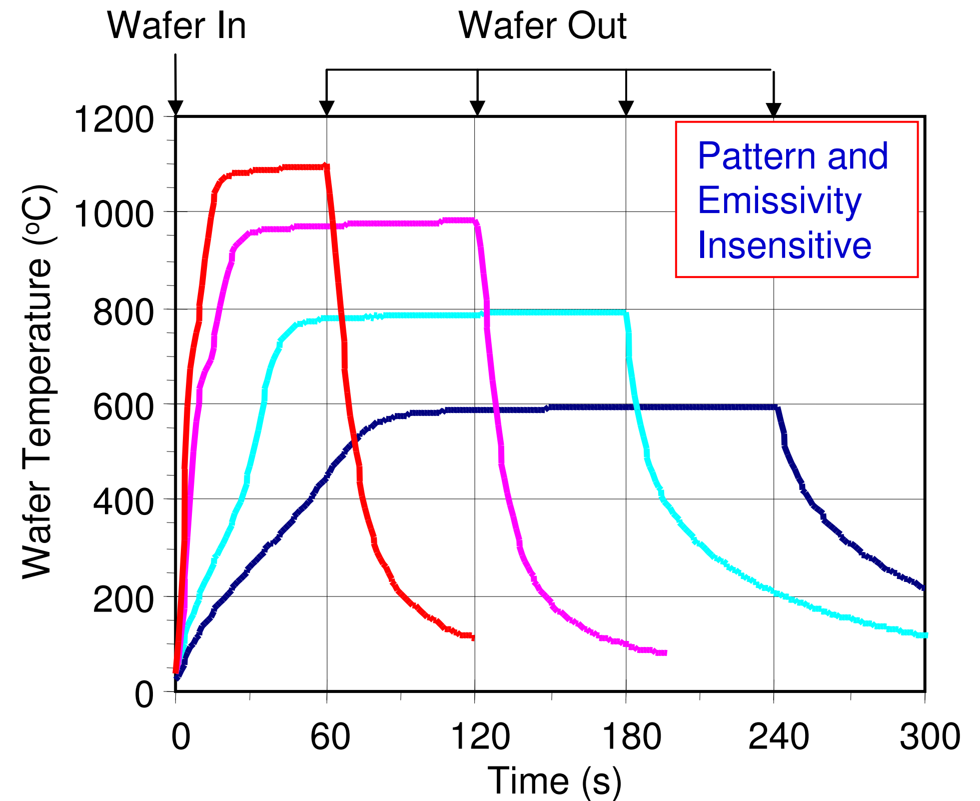
Isothermal Process Chamber and Wafer Temperature Profiles

SRTF-302LP





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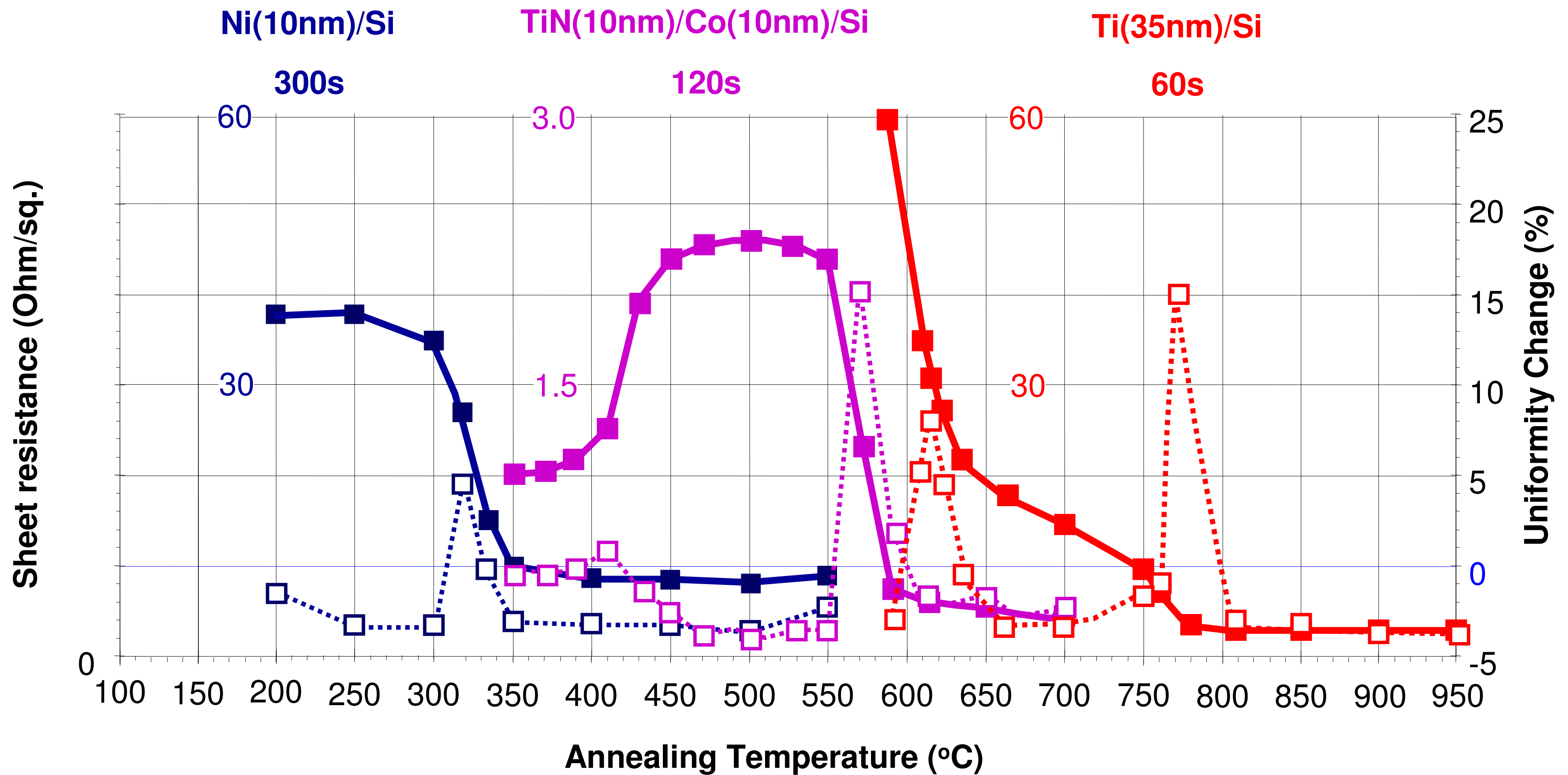
Temperature Sensitivity of Sheet Resistance of Various Silicides

Process Capability of SRTF-302LP



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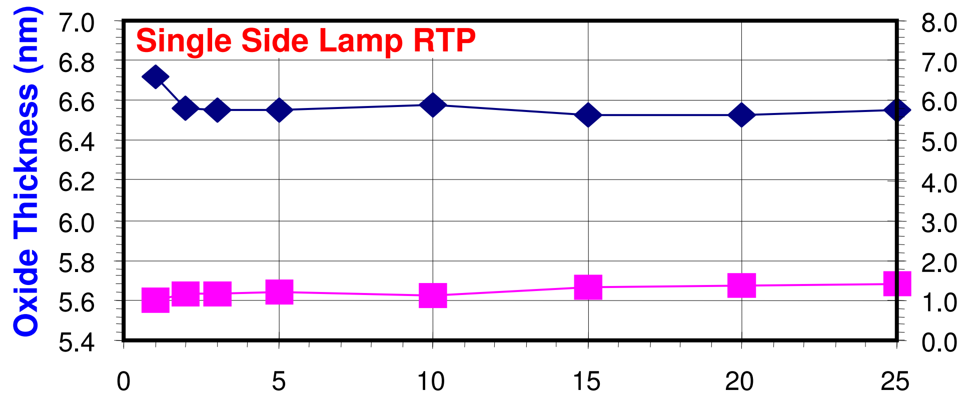
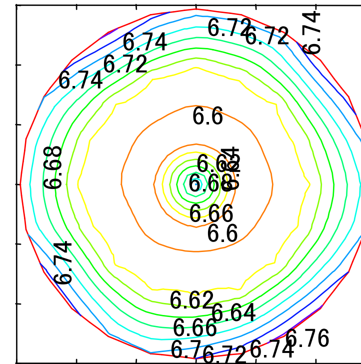
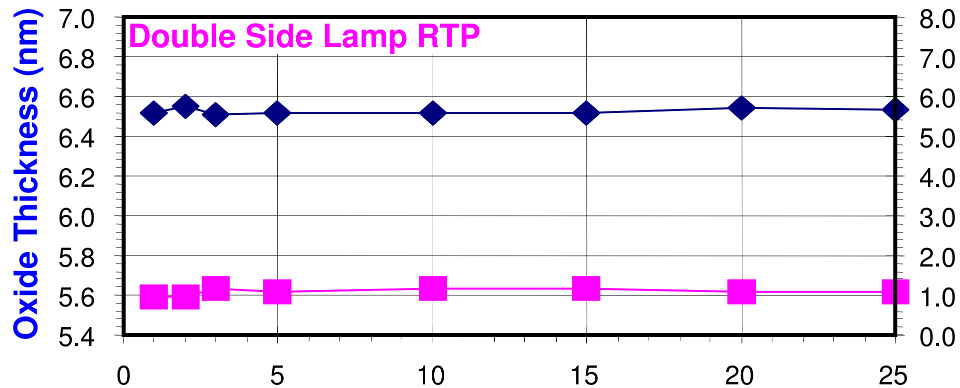
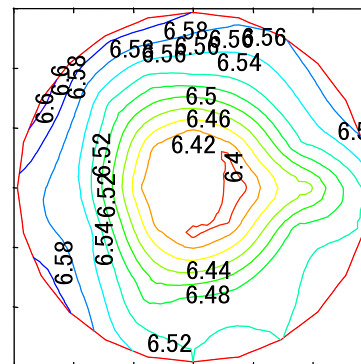
RTO Repeatability: RTP System Dependence





Single Side Lamp RTP





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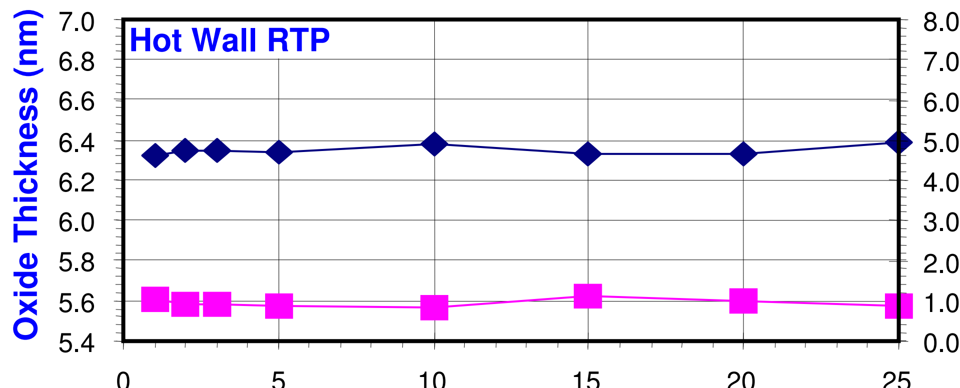

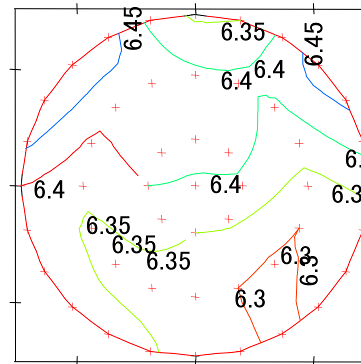

Hot Wall RTP

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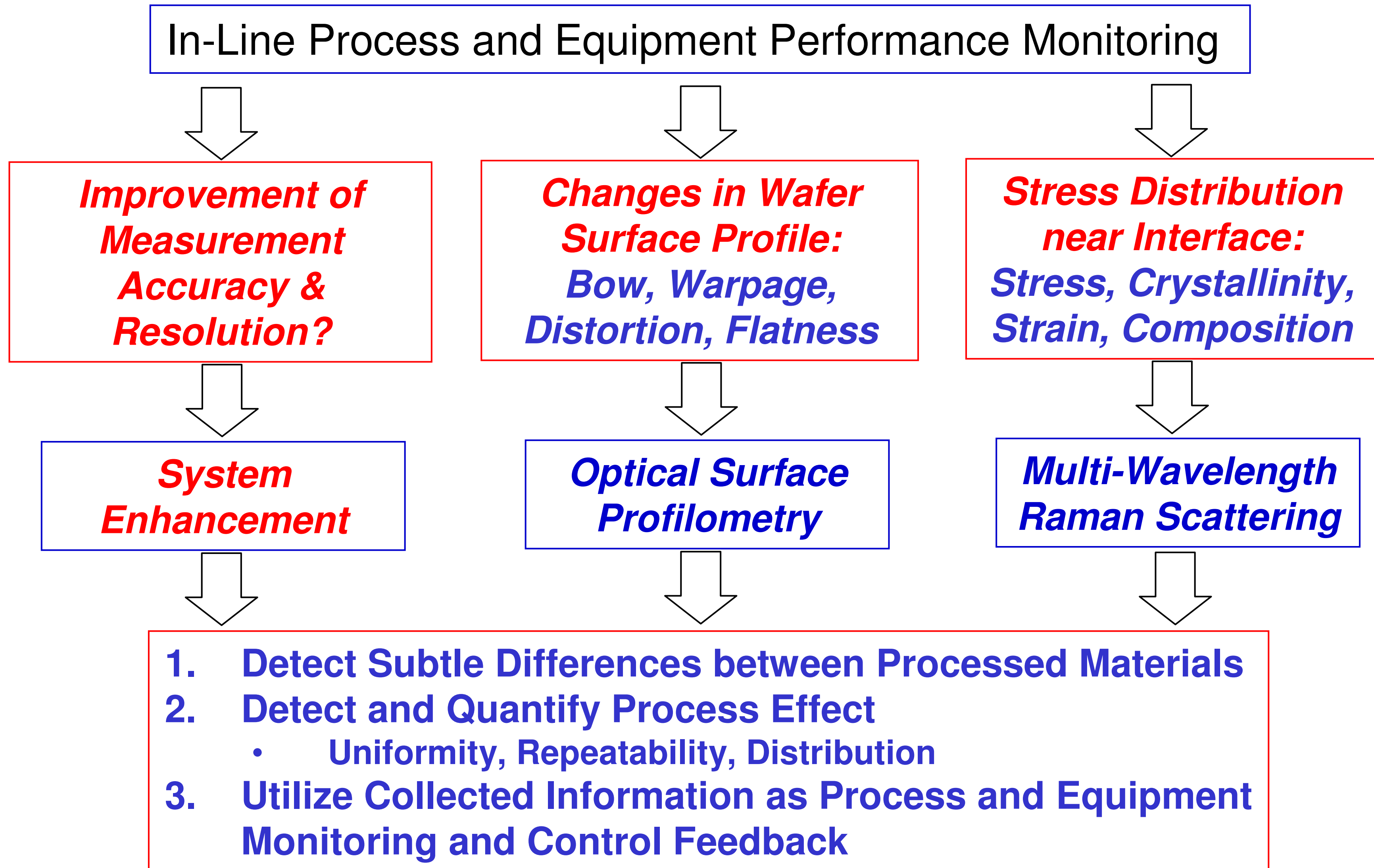
Strategy for Manufacturing Process and Quality Improvement



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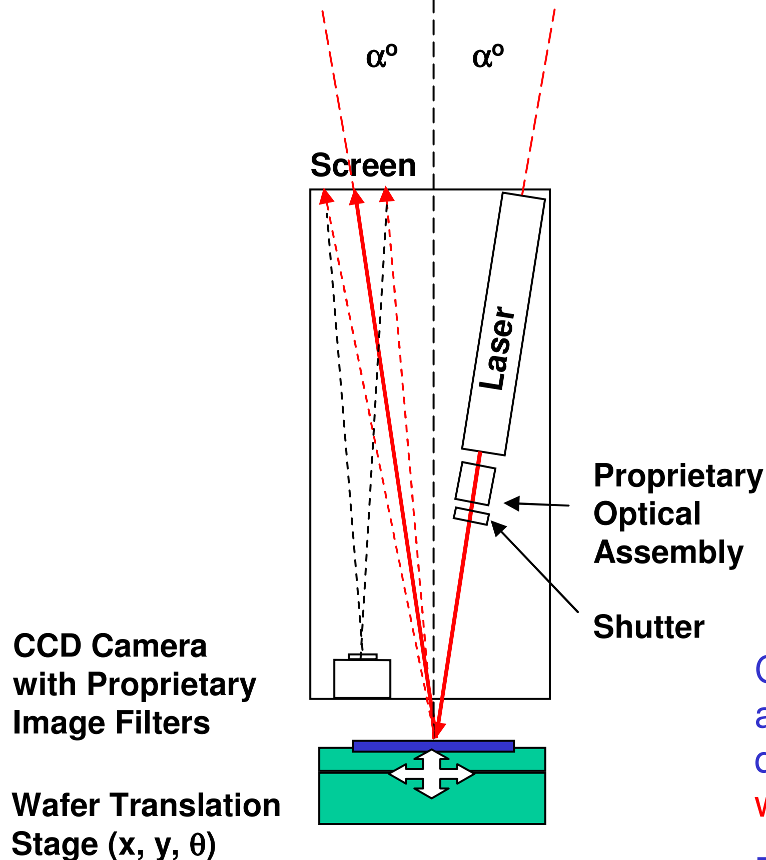
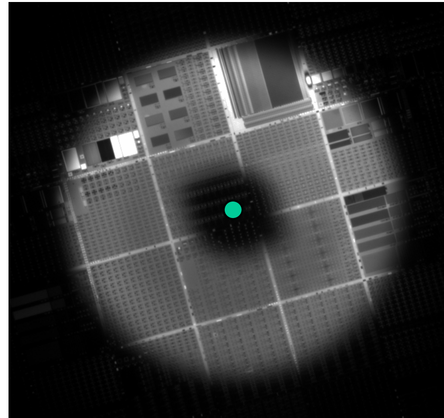
OSP-300: Operating Principles

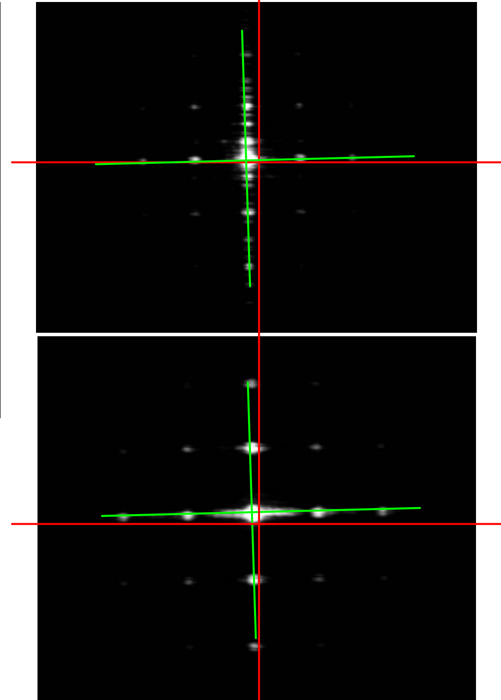
Angle of Reflection = Angle of Incidence
(zero order diffraction)



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

Vector Plot	Intensity	Height Profile	Beam Position	Curvature	3D Map

DA0525.01 #3206 2008/03/05 19:25:46

Intensity — Intensity Mean — Range=174.0 Interval=2.0

Height — Height Mean — Range=36.3um Interval=1.0um

R(95%)=7.6 — 95% Value — Histogram — 95% Circle — Distribution Avg=4.1 sdev=1.8

Fitted Curvature — Actual Height Range — [110] [010] [-110] [-100] — -587.9m 17.5um — 699.1m 16.6um — 704.2m 16.7um — -563.5m 14.8um

Range = 100 micron — Z Y X — Notch

DA0525.03 #3207 2008/03/05 19:48:09

Intensity — Intensity Mean — Range=174.0 Interval=2.0

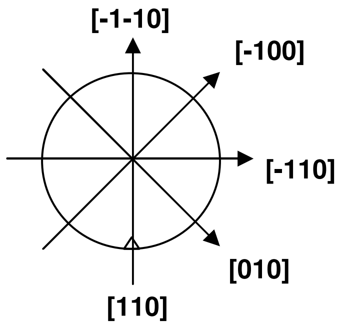
Height — Height Mean — Range=28.9um Interval=1.0um

R(95%)=5.6 — 95% Value — Histogram — Distribution Avg=3.6 sdev=1.3

Curvature — Fitted Curvature — Actual Height Range — [110] [010] [-110] [-100] — -592.5m 17.9um — -602.1m 15.6um — 697.4m 16.4um — 633.5m 13.9um

Range = 100 micron — Z Y X — Notch

Intensity Range — Contour Interval — Height Range — Contour Interval — Distribution Average — Distribution Std. Deviation



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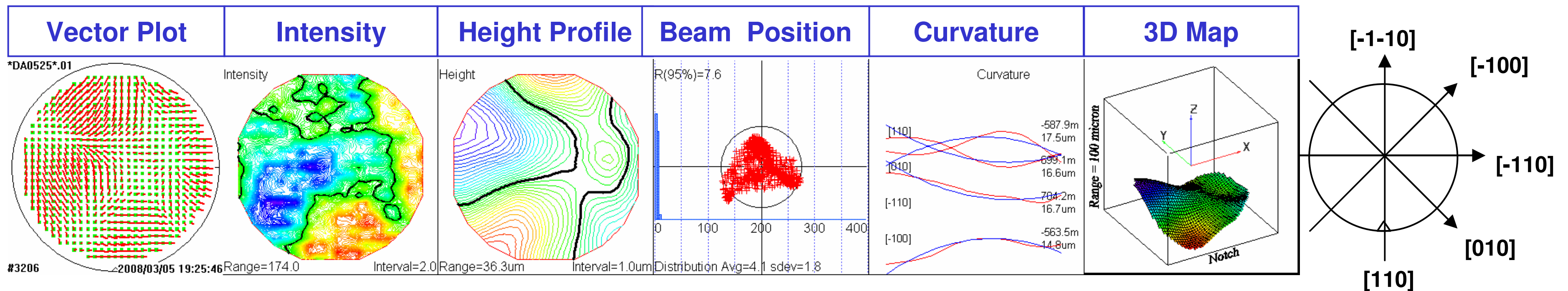
OSP-300: Wafer Curvature Estimation

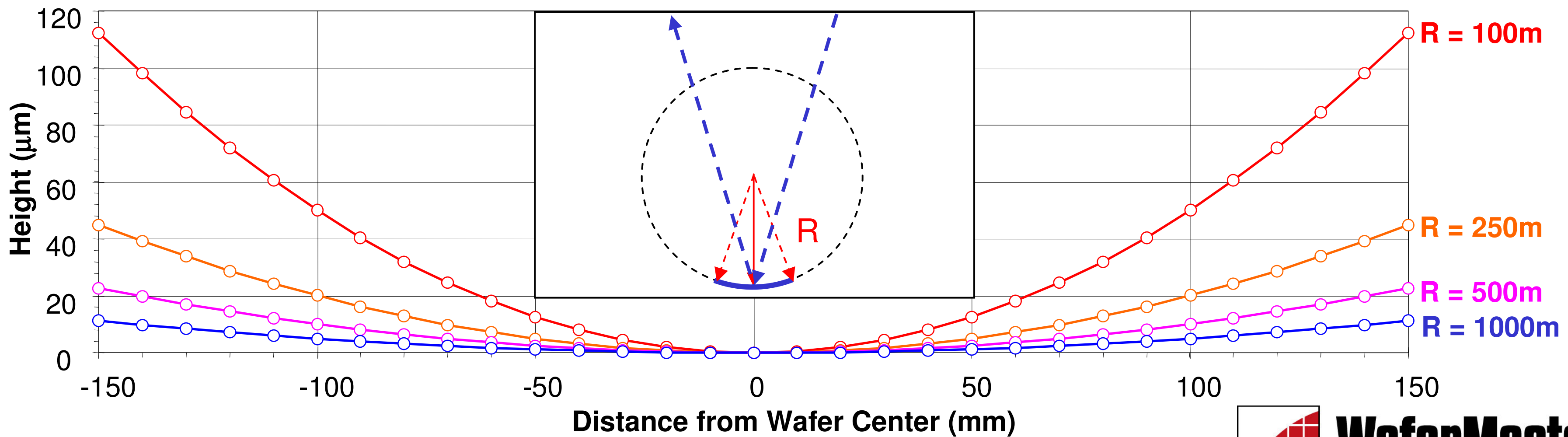
Measurement Parameters

- 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





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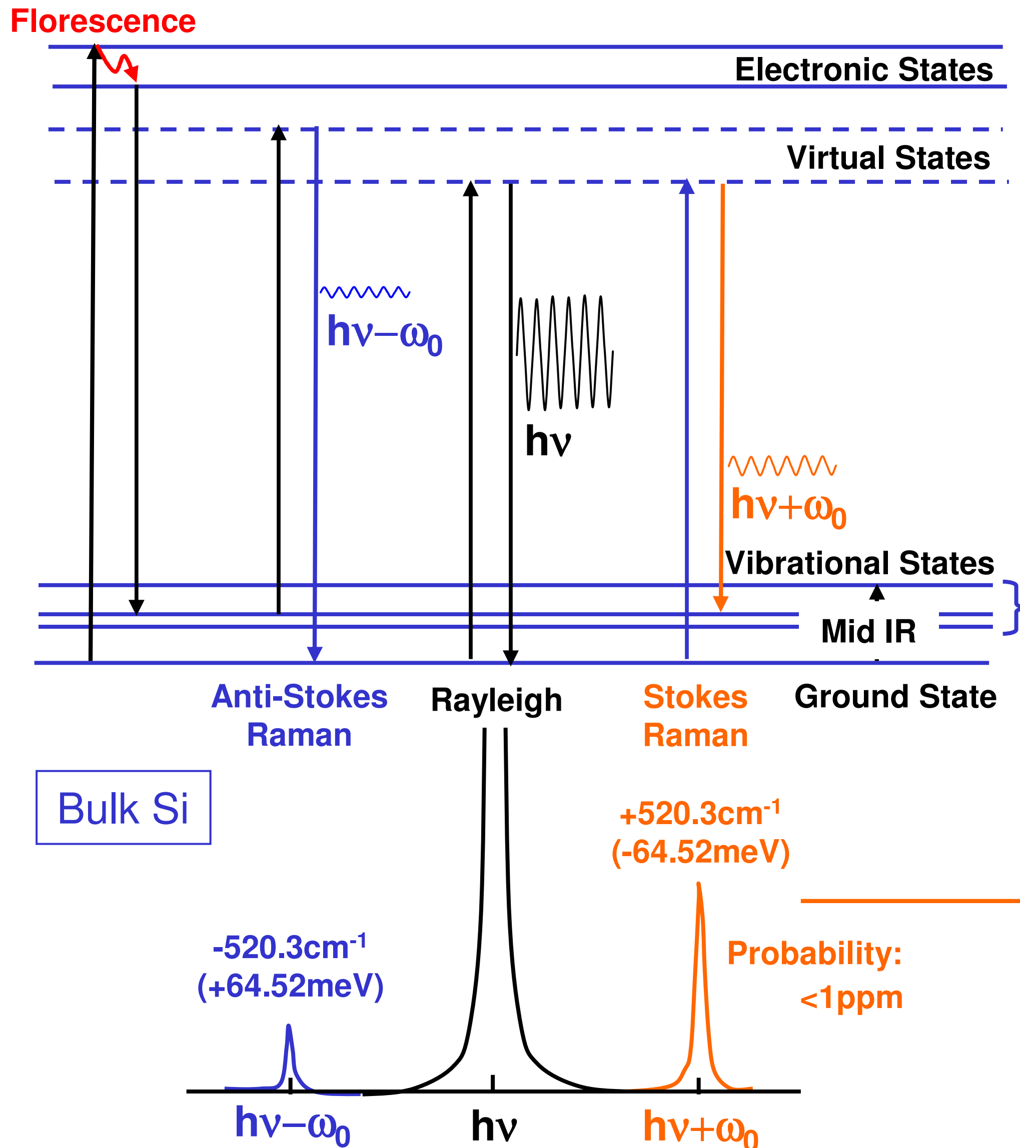
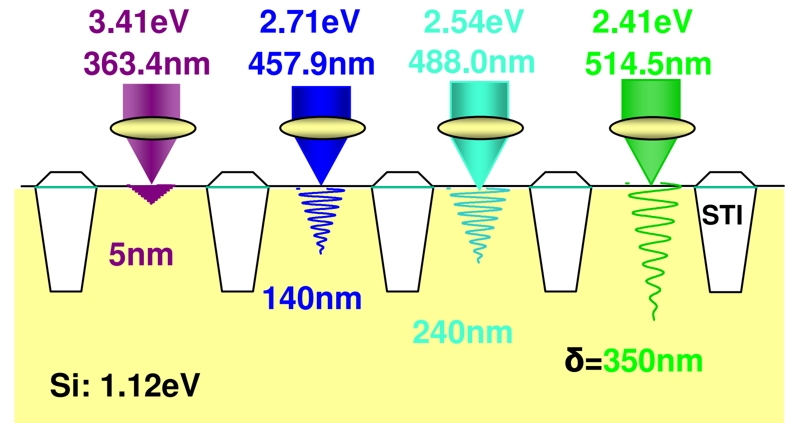
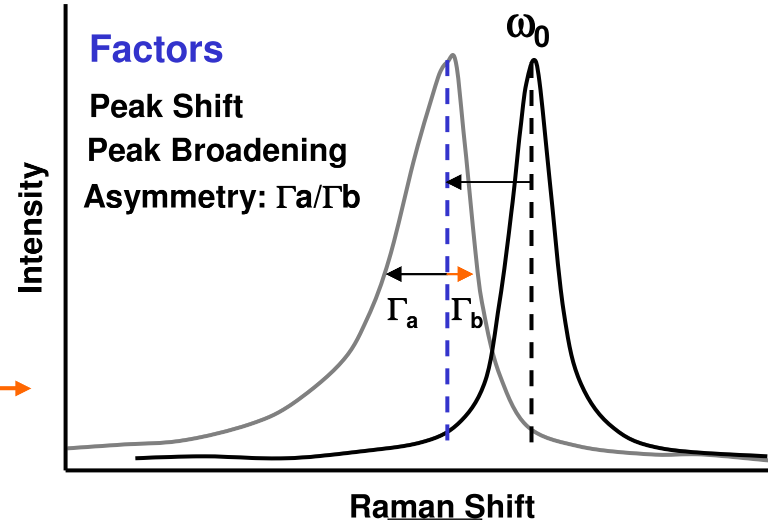
Raman Scattering: Lattice Stress & Strain Characterization







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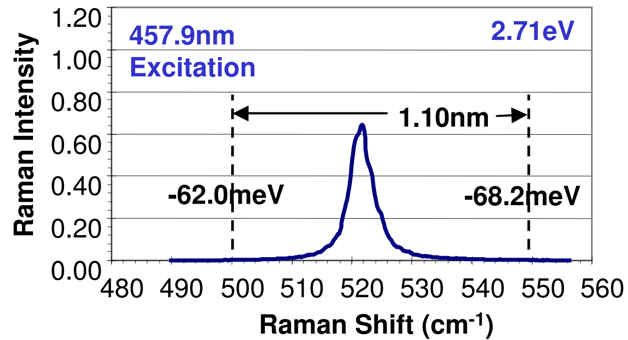
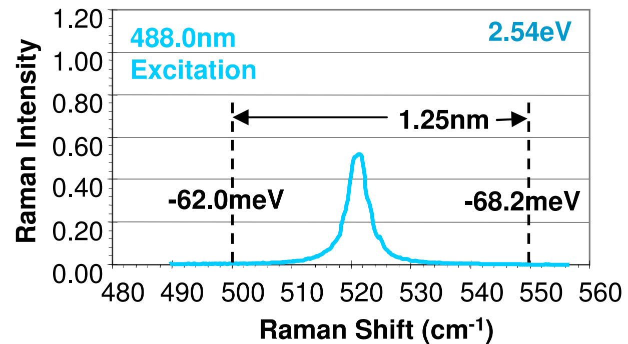
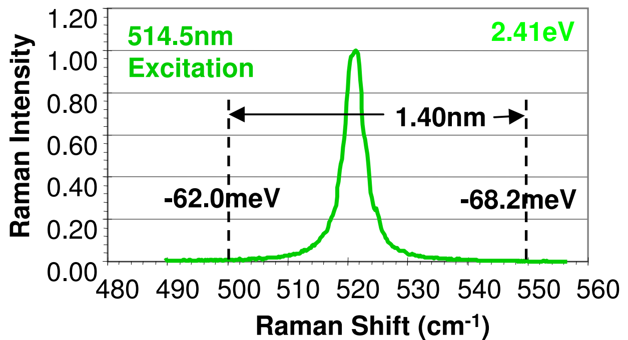
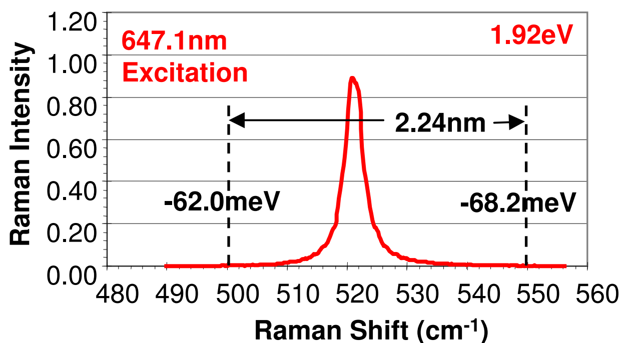
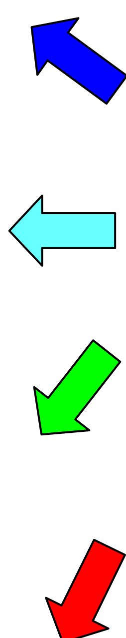
Raman and Photoluminescence Signals from Bulk Si

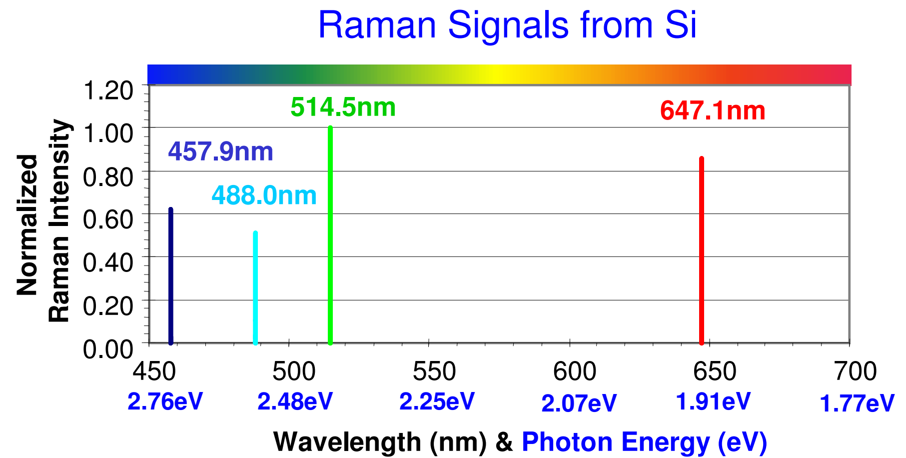


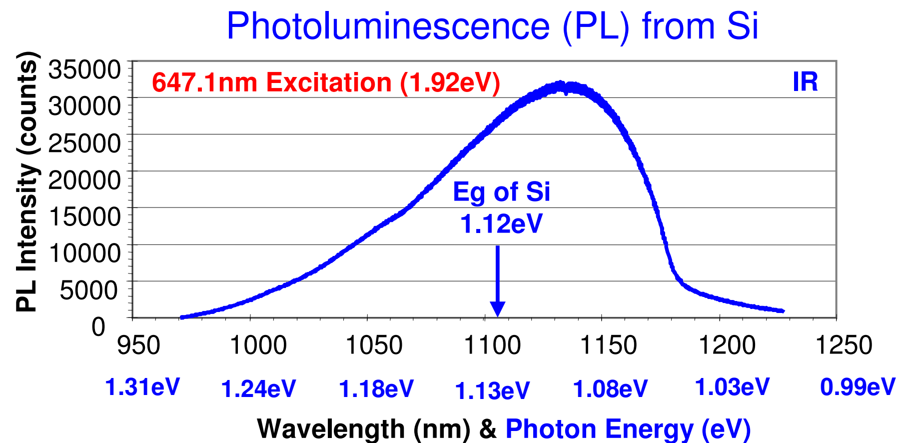












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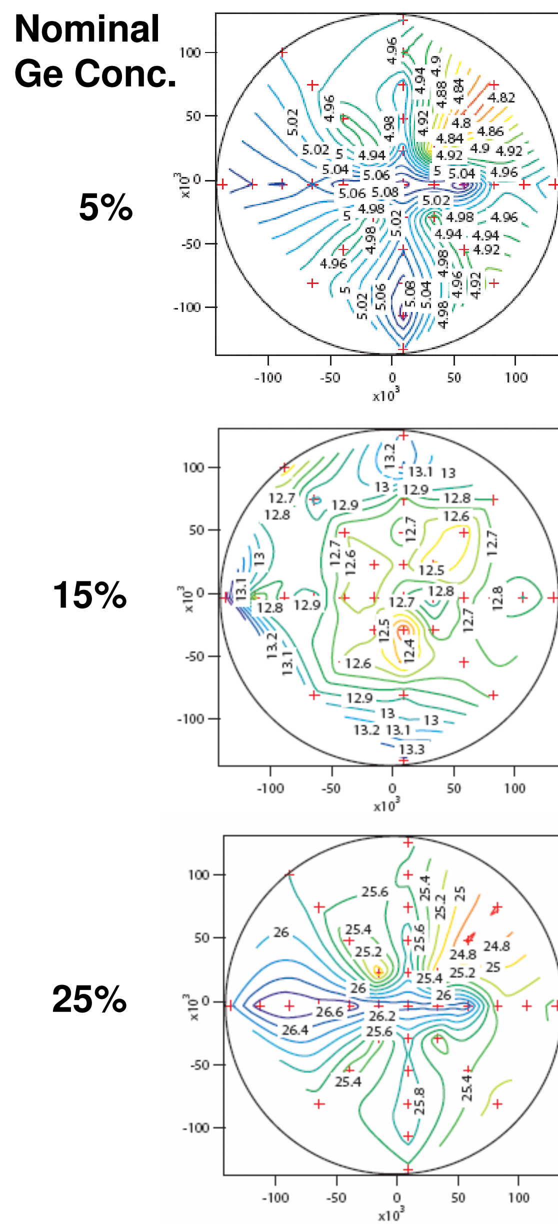
Ge Concentration Maps from Strained Si



Si

514.5nm Excitation

Si-Si in SiGe

Ge 15%

Ge 20%

Ge 25%

Ge 30%

Intensity (Counts)

Raman Shift (cm^{-1})

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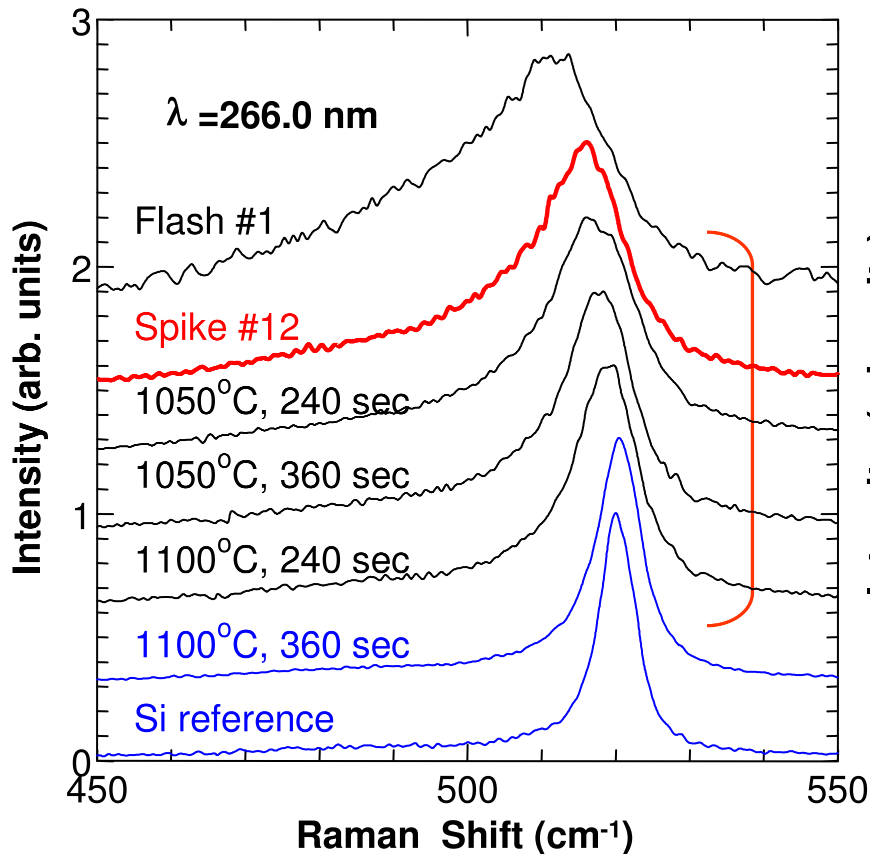
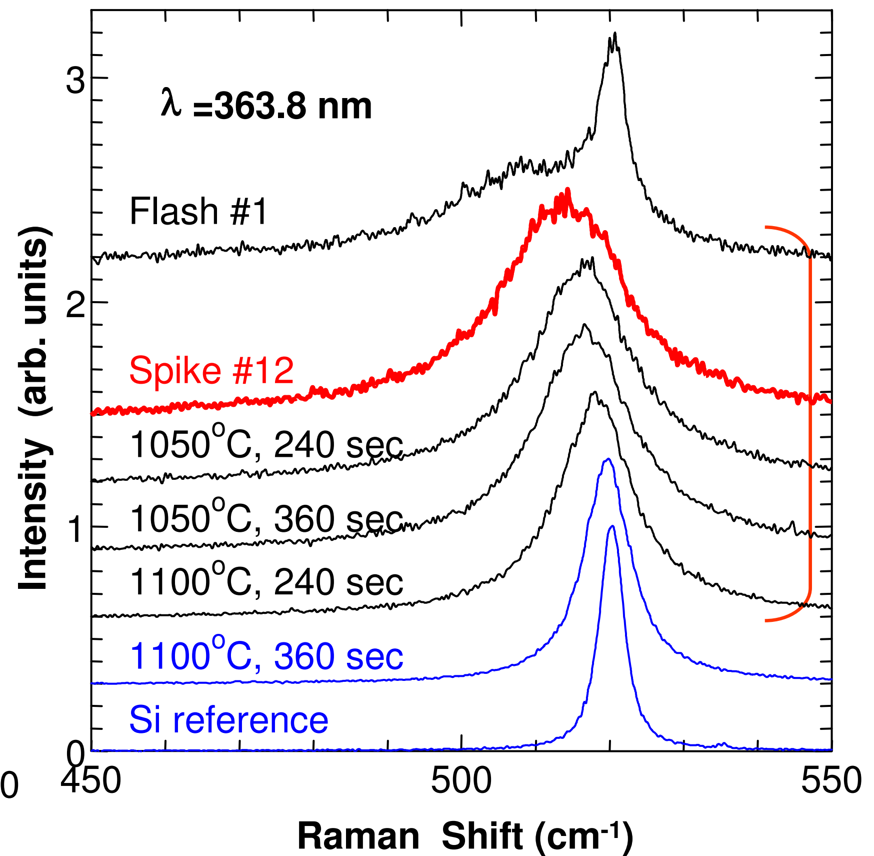
Raman Characterization: Implant Damages

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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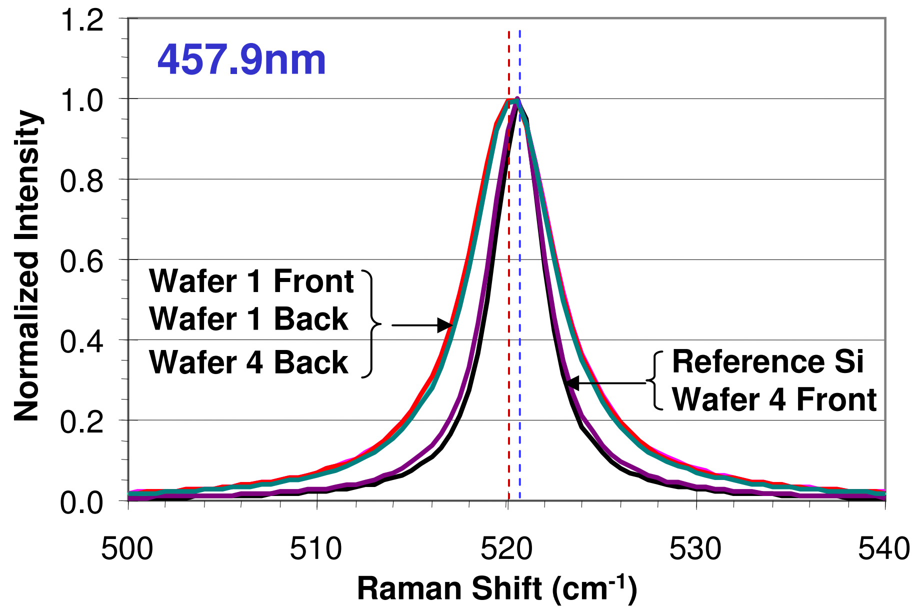
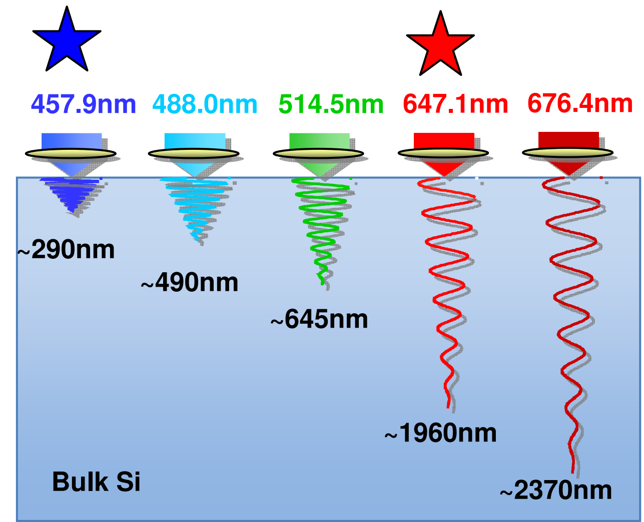
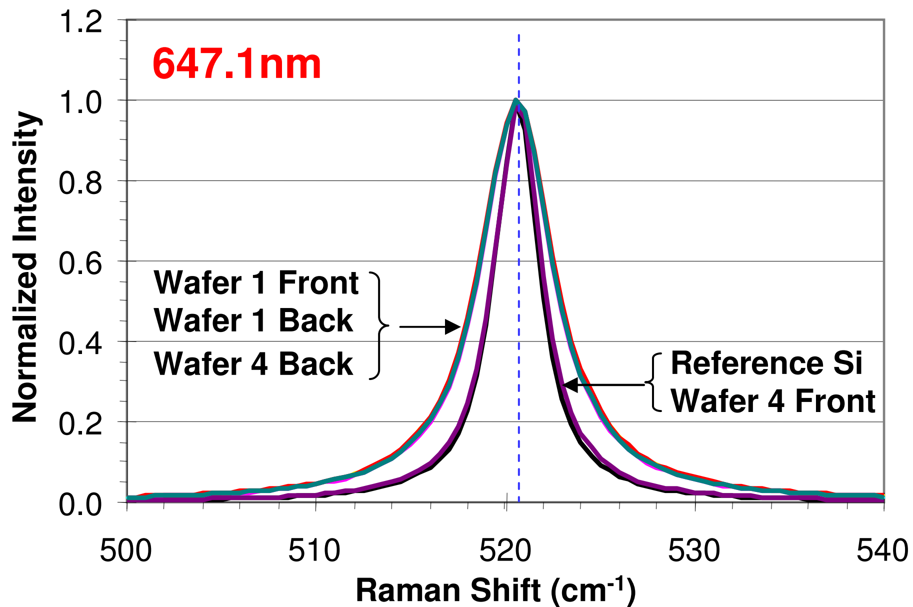
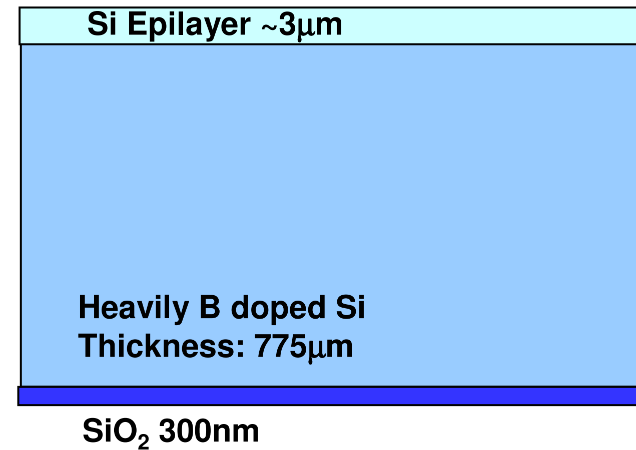
Raman Characterization: Epilayer Quality









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OSP-300 & MRS-300 Application Examples

RTO Film Characterization

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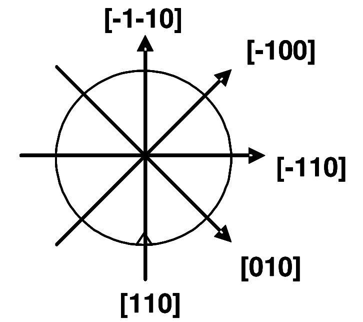
Site Flatness before and after RTO

		Vector Plot	Intensity	Height Profile	Reflected Beam Position	Curvature along Crystal Axes
Hot Wall RTA	Before RTO	New Wf Matrix Pre2 7, 20.02 2007/07/19 20:37:11	Intensity	Height	R(95%)<9.0665 Distribution	Curvature [110] 280m [010] 244m [-110] 283m [-100] 264m
	After RTO	New Wf Matrix Post.07 2007/07/24 21:48:49	Intensity	Height	R(95%)<8.8757 Distribution	Curvature [110] 285m [010] 253m [-110] 302m [-100] 272m
Single Side Lamp RTA	Before RTO	New Wf Matrix4 7, 23.05 2007/07/23 02:39:56	Intensity	Height	R(95%)<8.0024 Distribution	Curvature [110] 321m [010] 290m [-110] 333m [-100] 297m
	After RTO	MattVan Oxidation.07 #2642 2007/08/03 00:52:10	Intensity	Height	R(95%)<12.258 Distribution	Curvature [110] 261m [010] 224m [-110] 221m [-100] 205m
Double Side Lamp RTA	Before RTO	New Wf Matrix5 7, 23.04 2007/07/23 04:31:58	Intensity	Height	R(95%)<8.3626 Distribution	Curvature [110] 312m [010] 269m [-110] 314m [-100] 291m
	After RTO	MattVan Oxidation.04 #2636 2007/08/02 19:56:12	Intensity	Height	R(95%)<13.021 Distribution	Curvature [110] 205m [010] 239m [-110] 245m [-100] 351m

1030°C



Avg. = 5.17nm
Unif. = 0.75%

No Change

Avg. = 5.67nm
Unif. = 0.49%

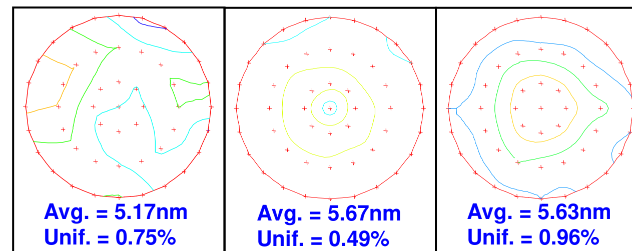
Distortion

Avg. = 5.63nm
Unif. = 0.96%

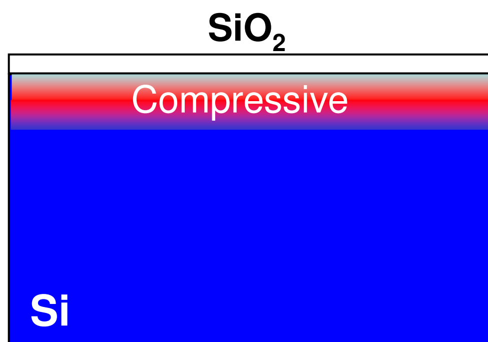
Distortion

Si Stress Change after RTO at 1030°C

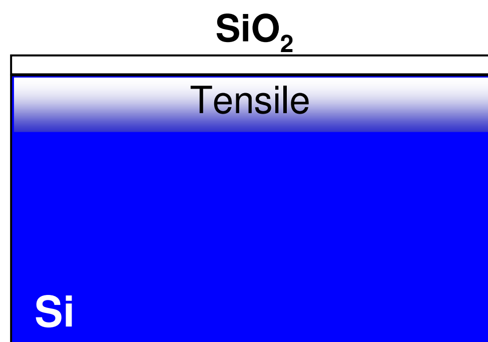
RTP System Dependence



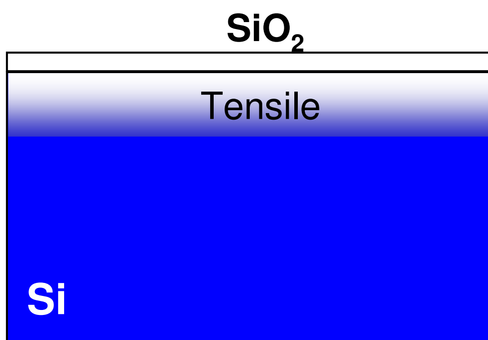
Hot Wall RTP



Single Side Lamp RTP

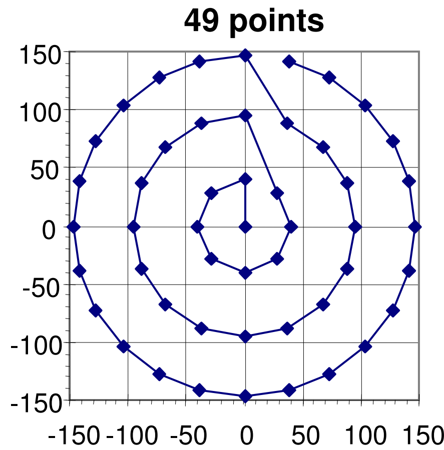


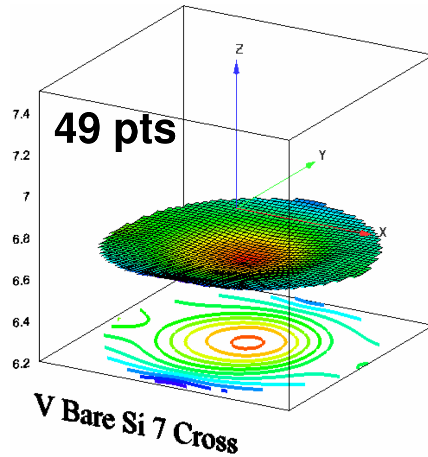
Double Side Lamp RTP

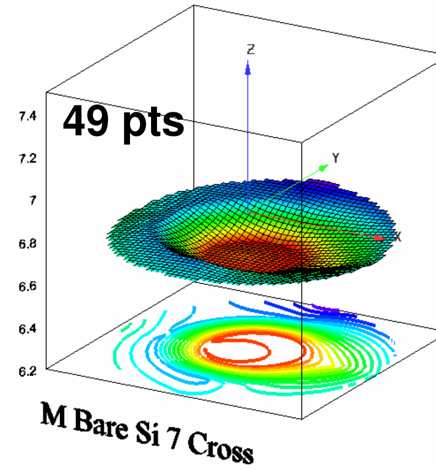


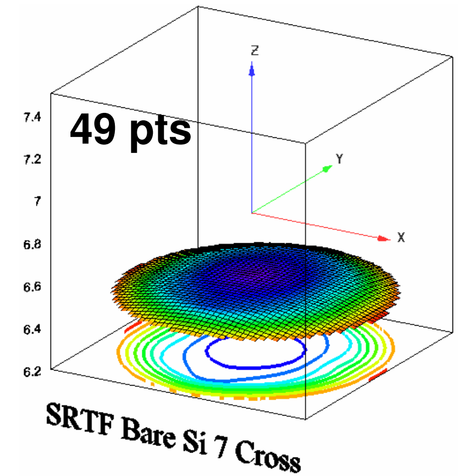
Effect of Lateral Resolution or Measurement Points

Reality of RTO Process Uniformity





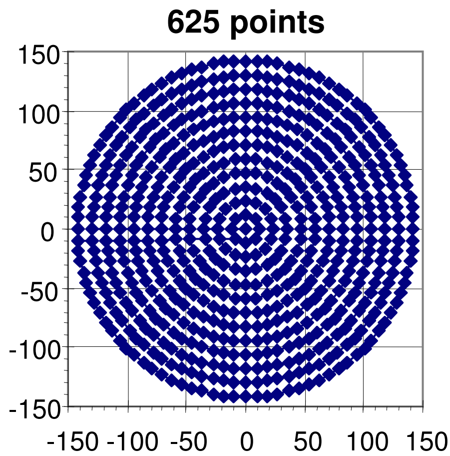


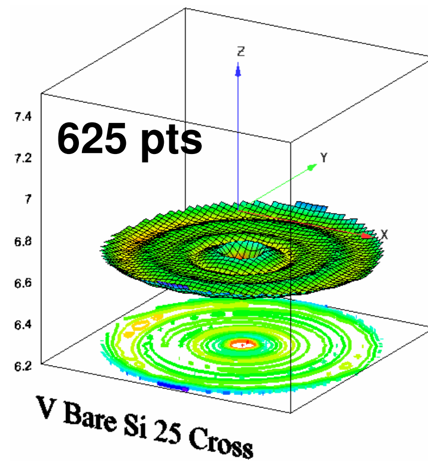


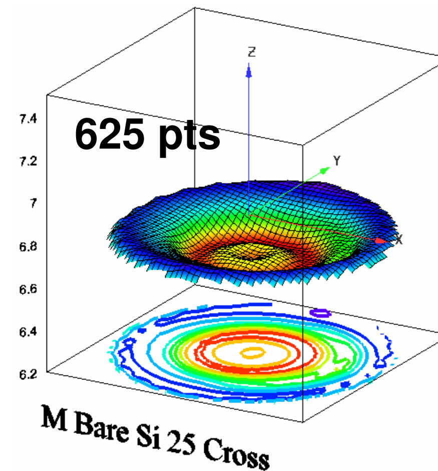
Single Side Lamp RTP

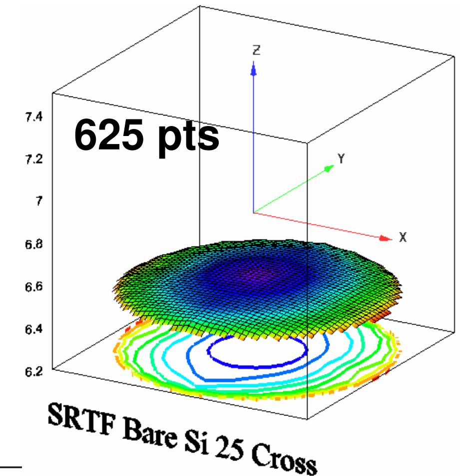
Double Side Lamp RTP

Hot Wall RTP









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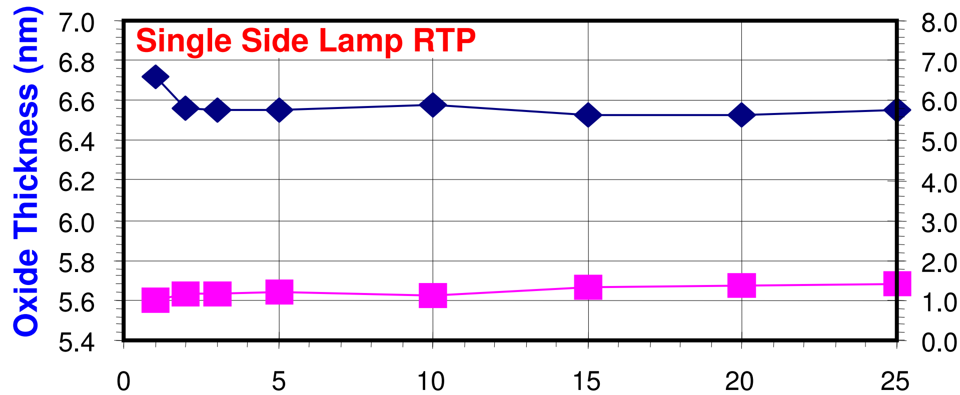
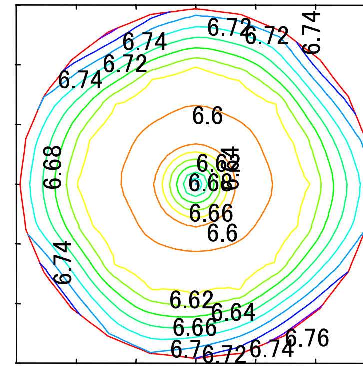
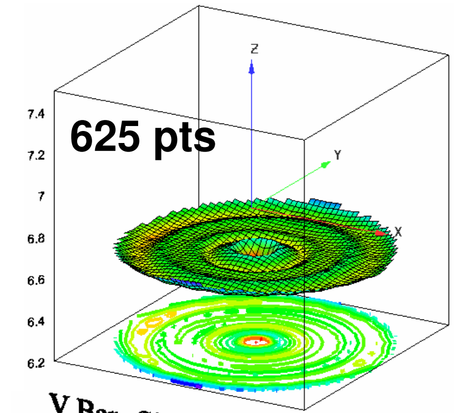
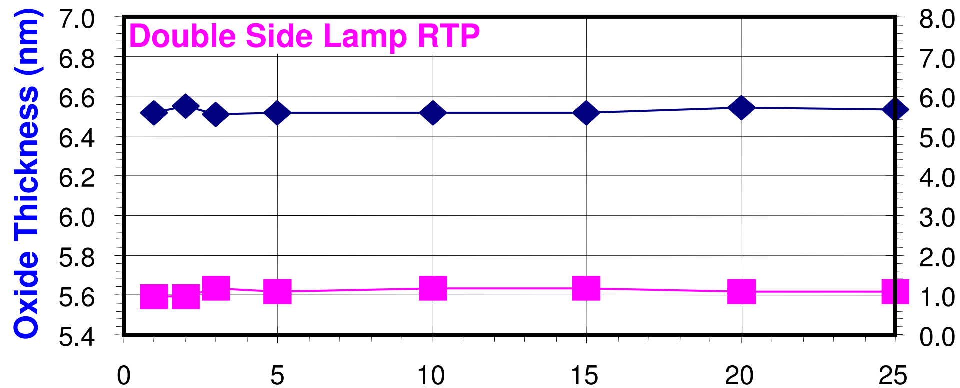
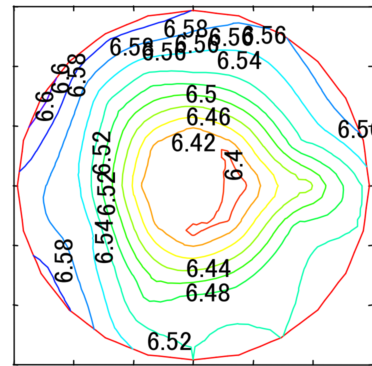
RTO Repeatability: RTP System Dependence

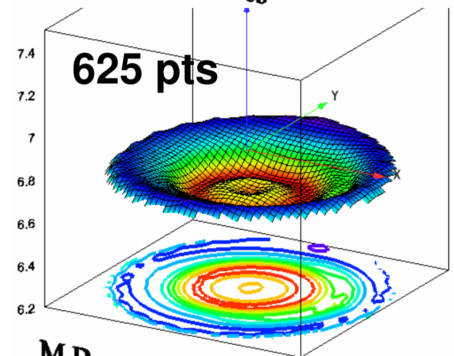


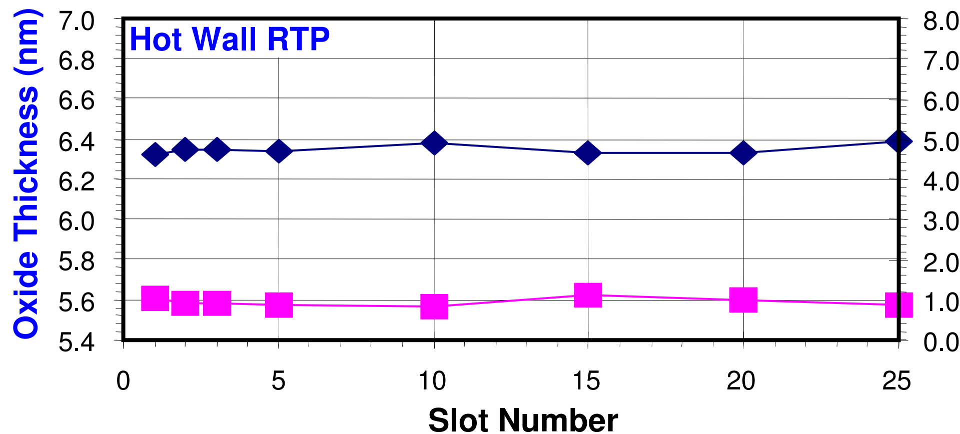


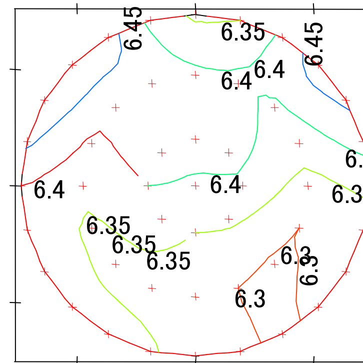


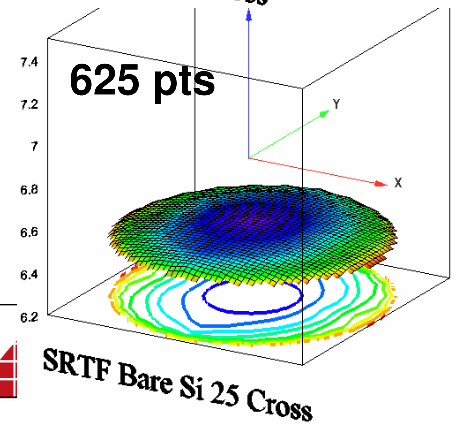












Summary

- 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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