Comprehensive Characterization of B^+ Implanted Silicon after Rapid Thermal Annealing

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Dublin, CA

USA

Outline

- Objectives: Visualization of Invisible Si Material Properties
  - Surface
  - Interface
  - Bulk
  - Defects
  - Charge Distribution
  - Stress/Strain
  - Band Bending
- Experiment:
  - Implanted Wafers
    - $^{11}B^{+}$ 1keV $1x10^{15}$ atoms/cm^2
  - RTA System (Hot Wall System)
    - Resistively heated single wafer rapid thermal furnace (SRTF)
  - Annealing Conditions
    - Temperature: 850°C~1050°C
    - Time 30s~180s (Residence time in SRTF)
      1s~150s (Equivalent soak time in lamp-based RTP)
    - Atmosphere: 1 atm, N_2
  - Multiwavelength Room Temp. Photoluminescence (RTPL)
- Results and Discussions
- Prospects

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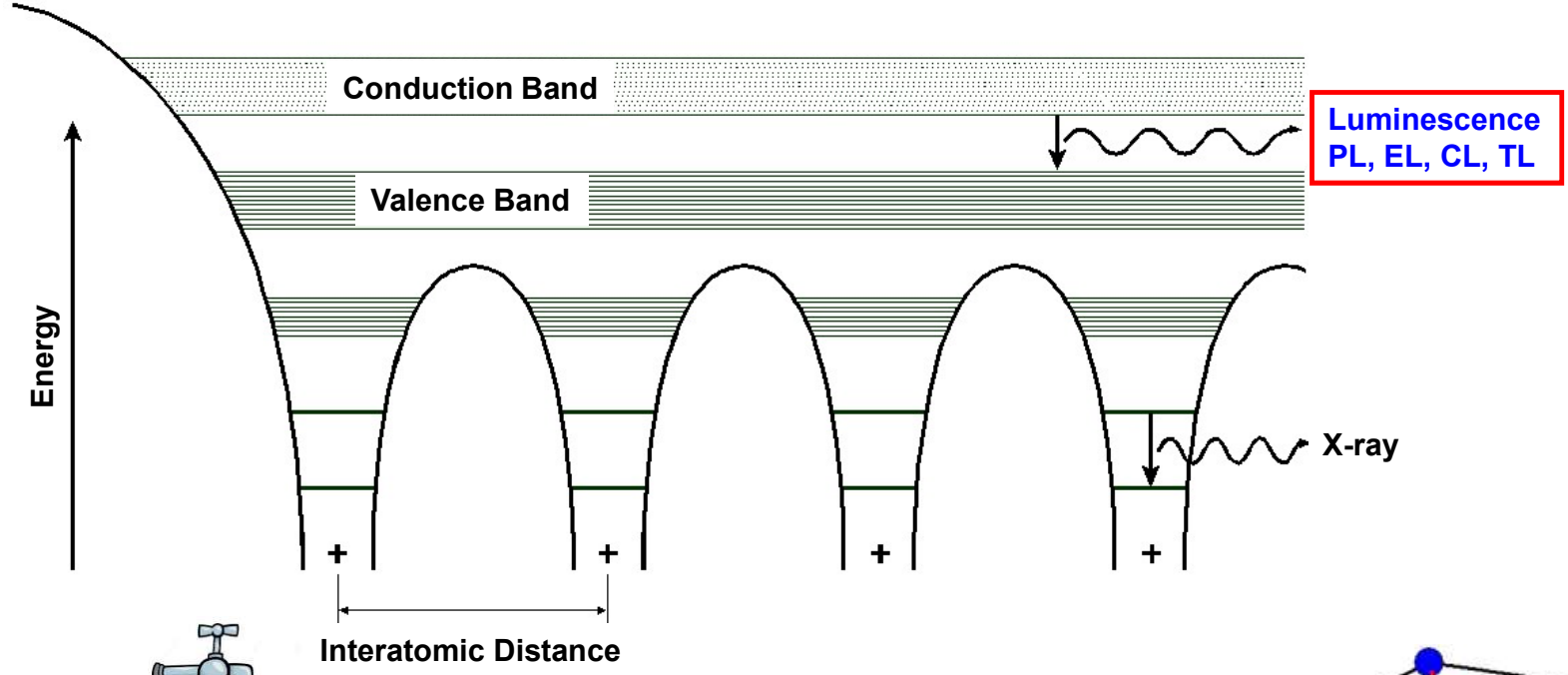
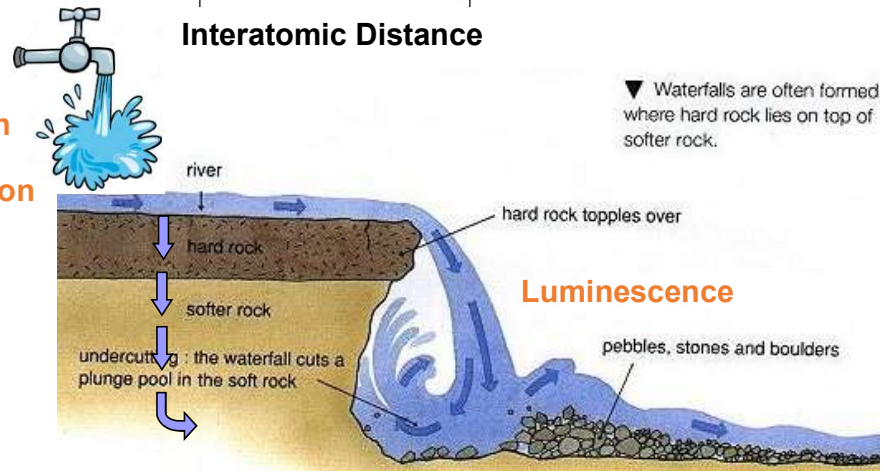
Band Structure of Semiconductors

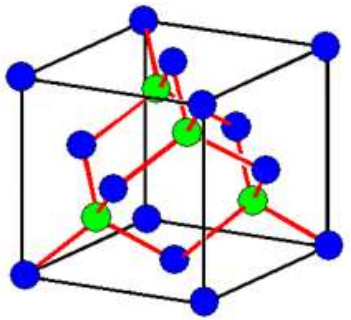


Excitation

Conduction Band

Valence Band





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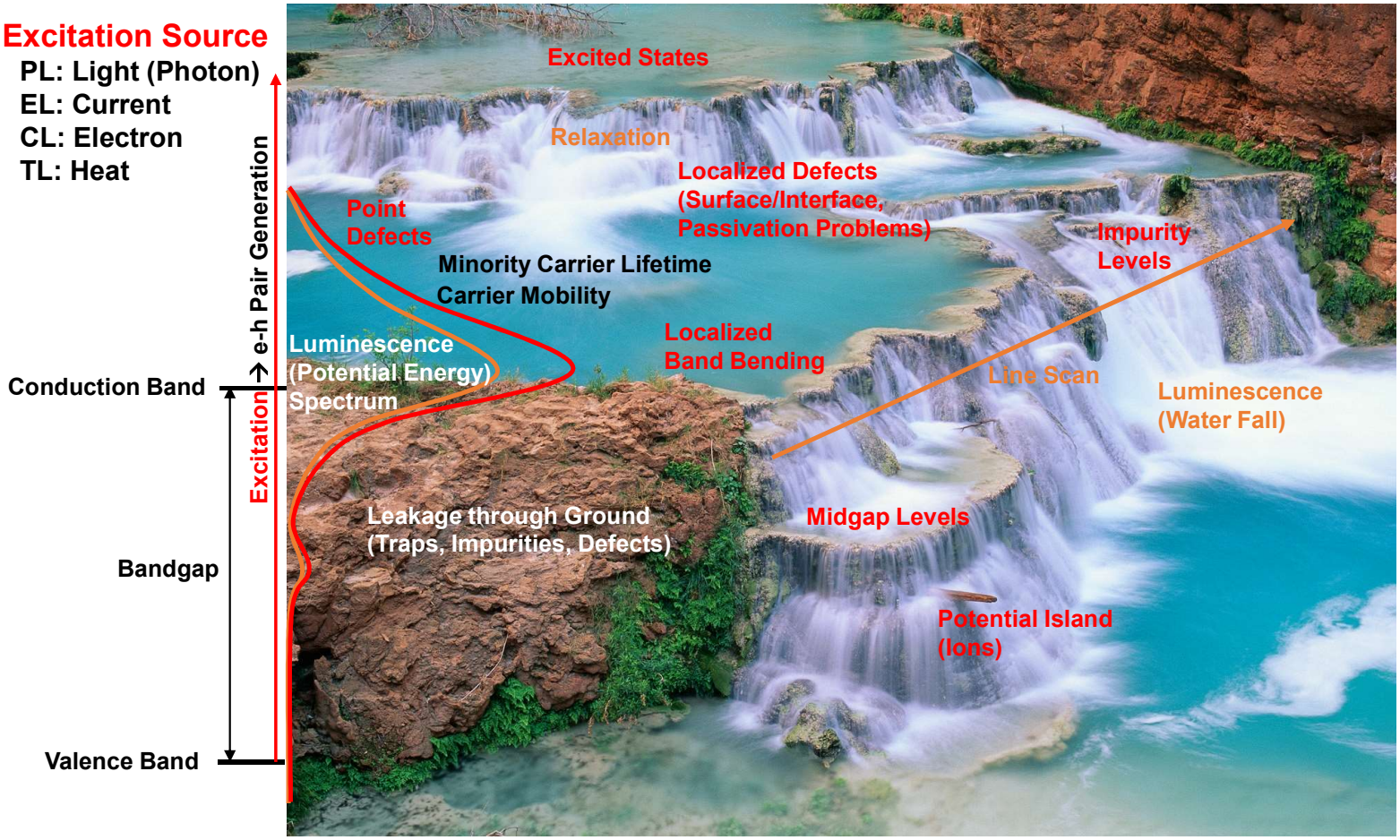
Detailed Information Needed for Proper Interpretation



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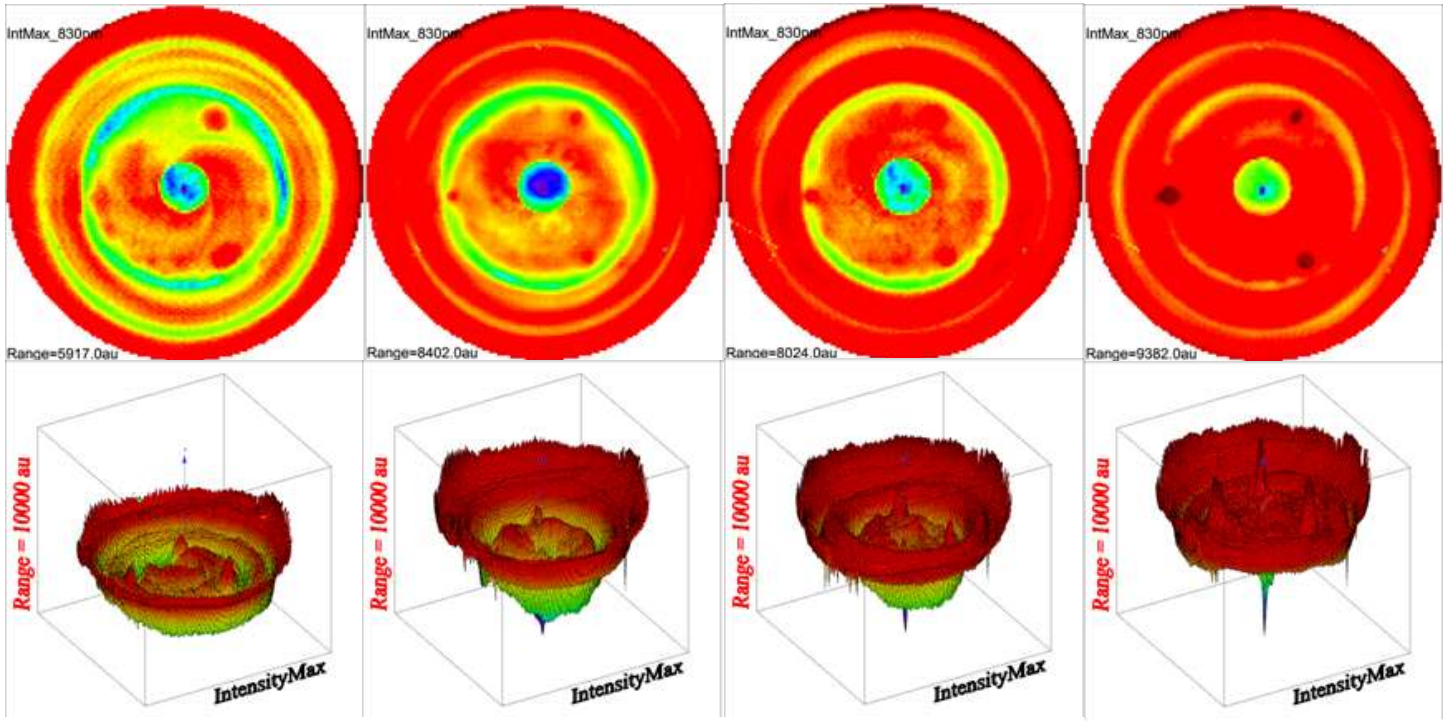
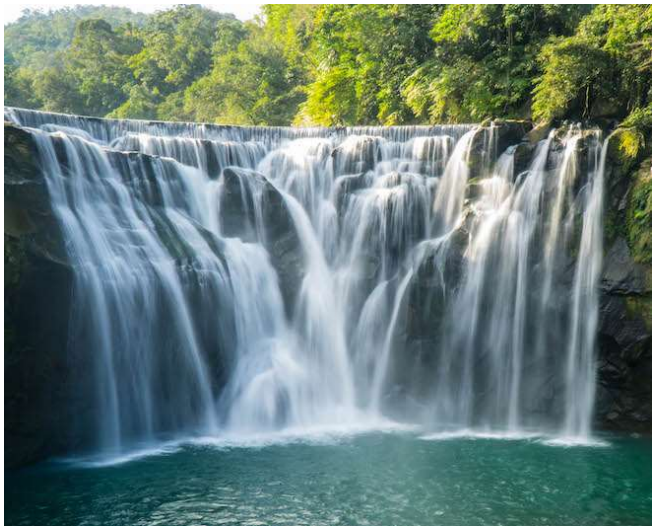
PL Mapping Examples (SiO_2/Si)

SiO_2/Si Interface Quality Monitoring

Wafer A | Wafer B | Wafer C | Wafer D





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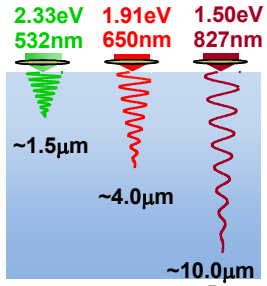
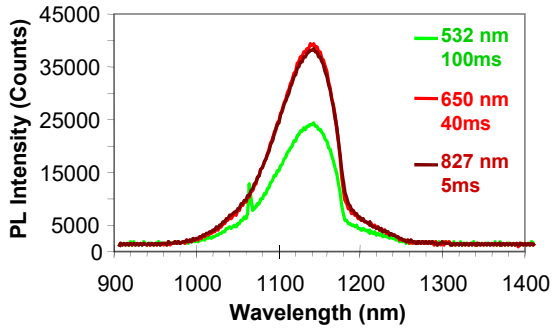
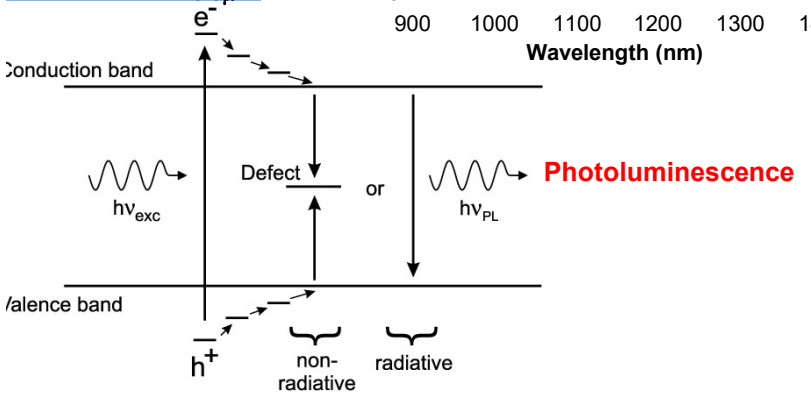
MPL-300: Multiwavelength Photoluminescence

Multiwavelength Photoluminescence Spectroscopy: The most direct way to measure band-gap energies, dopant activation, electrically active defects, plasma induced damage (PID), dielectrics/Si interface quality, metal contamination which affect minority carrier lifetime and electron mobility characteristics of the semiconductor.







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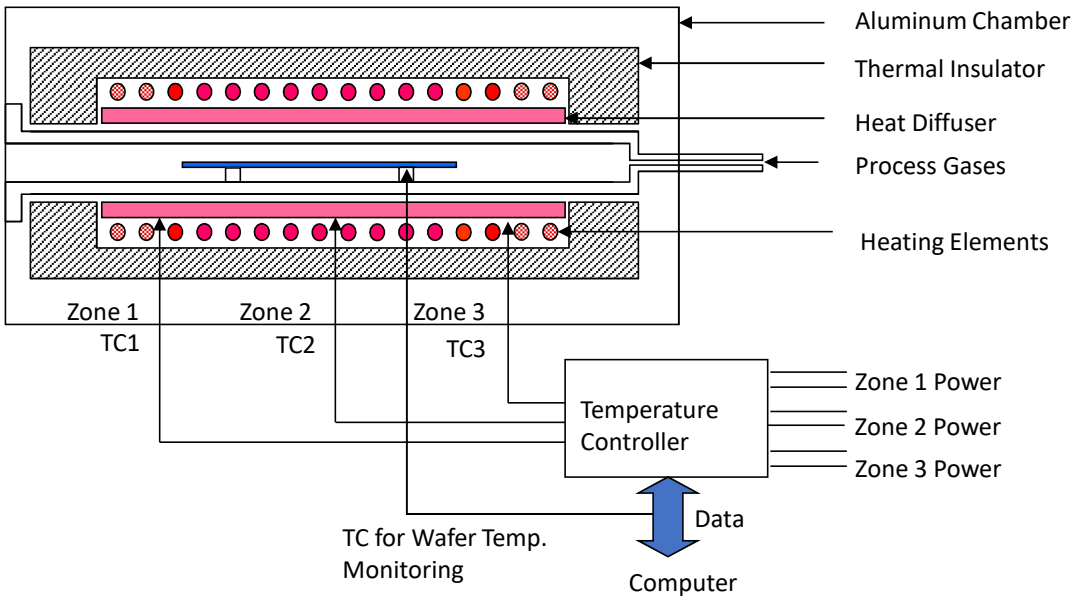
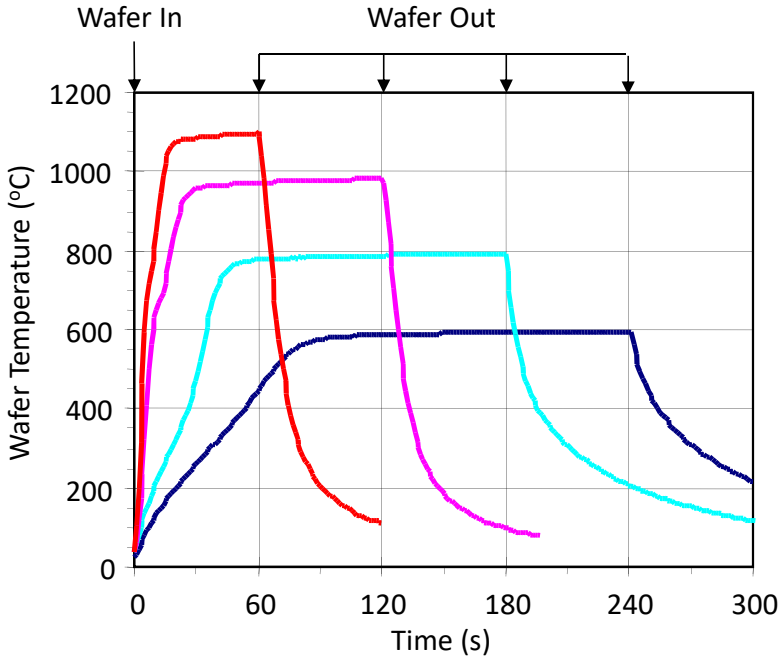
Single Wafer Rapid Thermal Furnace (SRTF)

Hot Wall RTA Process Chamber



Wafer Temperature Profile



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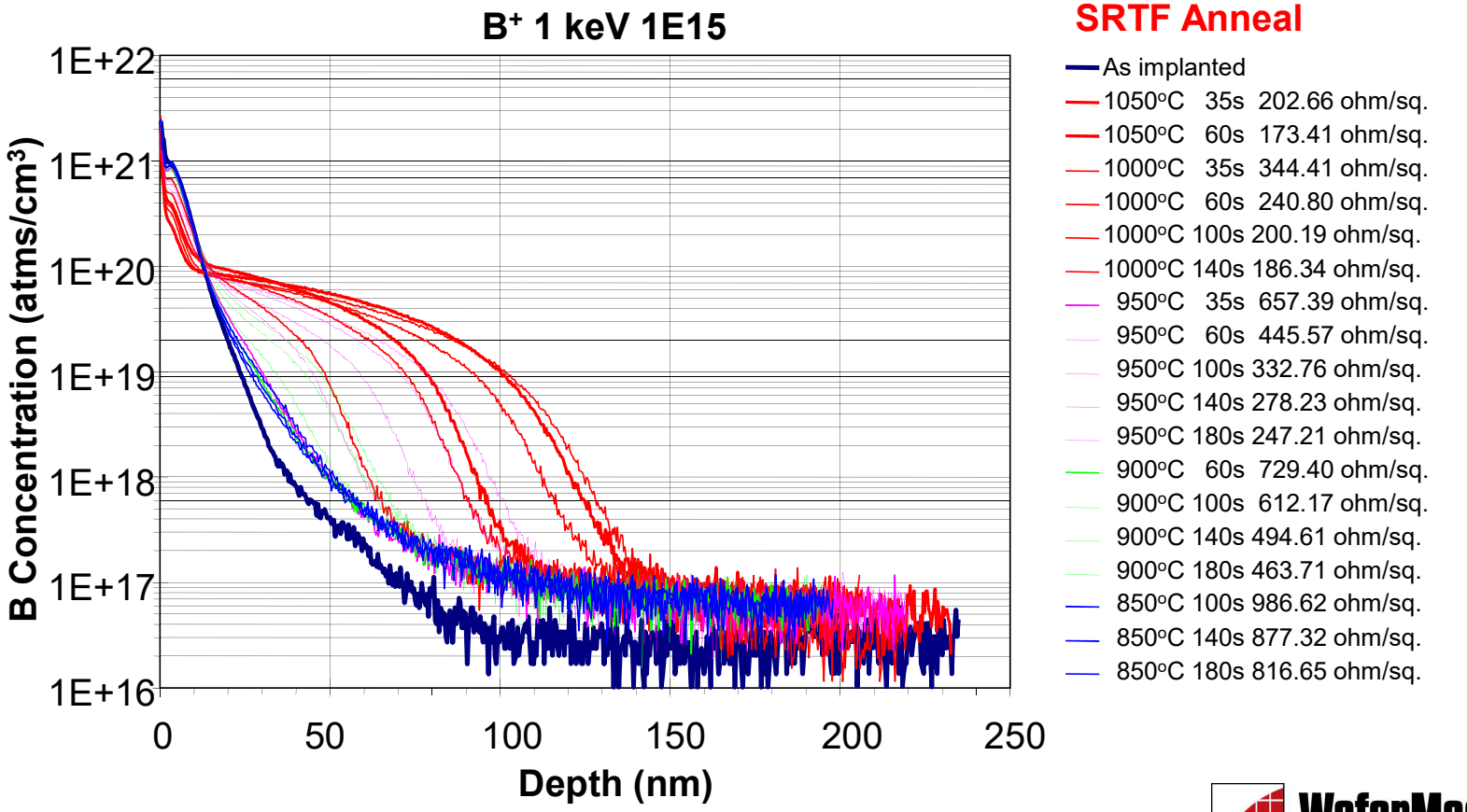
Boron Diffusion from Limited Source after RTA



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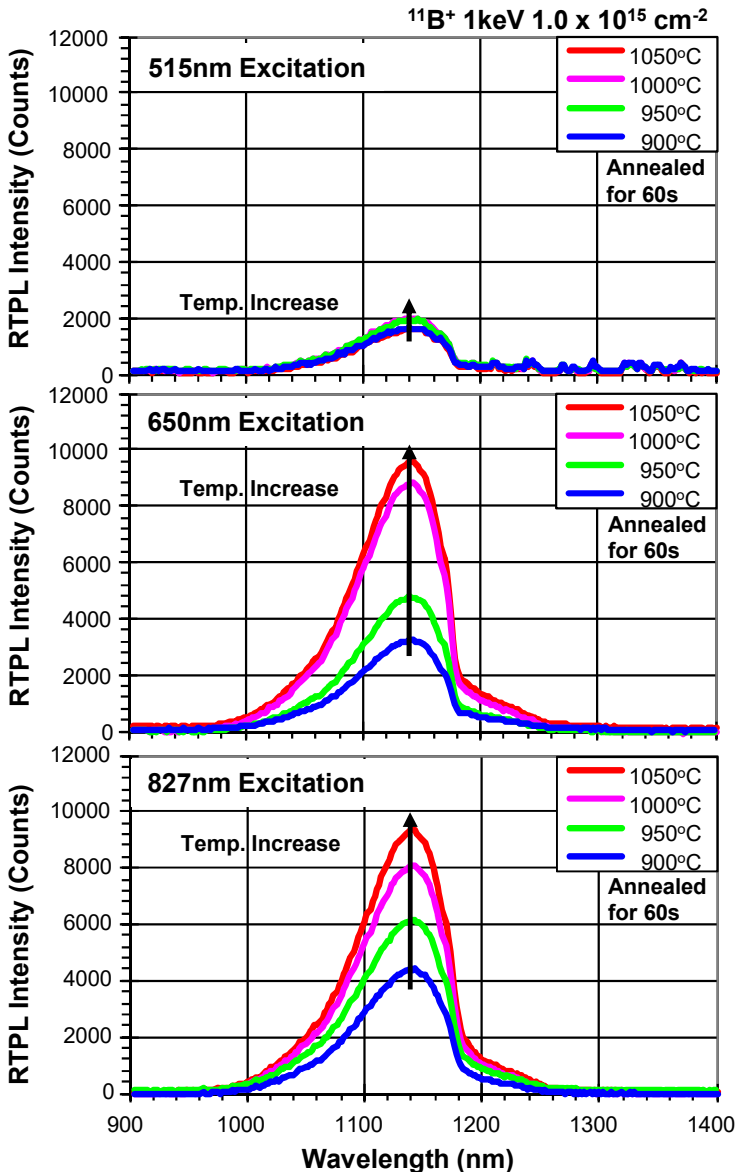

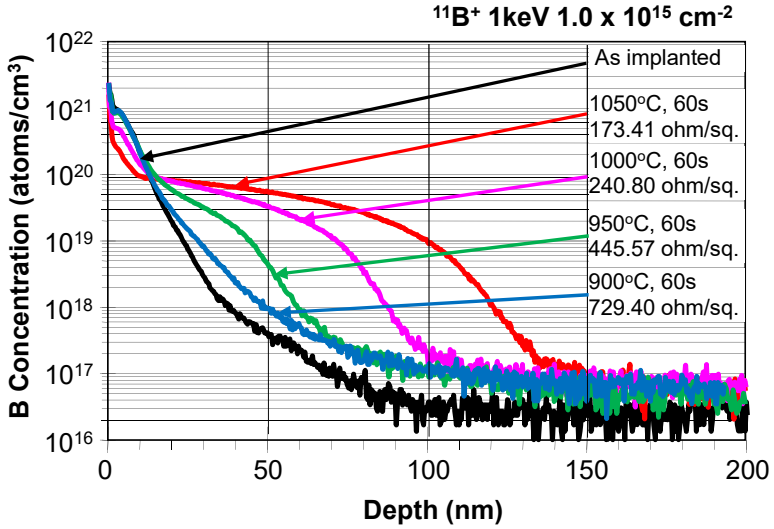

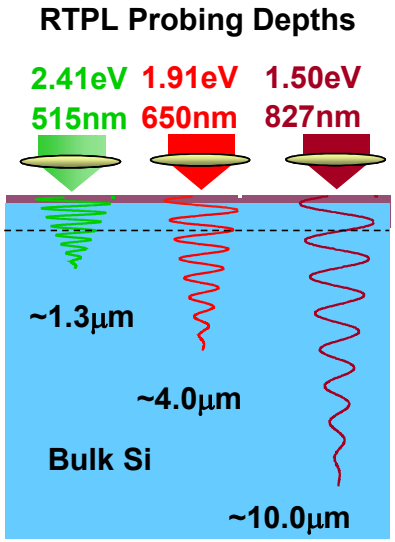

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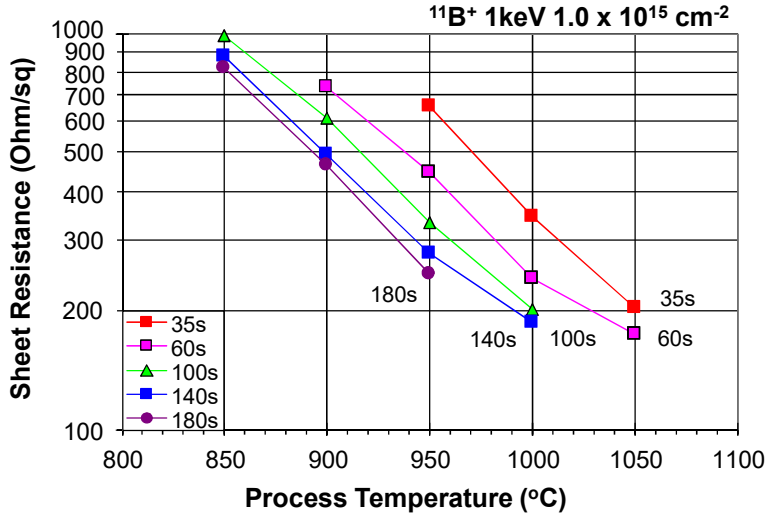

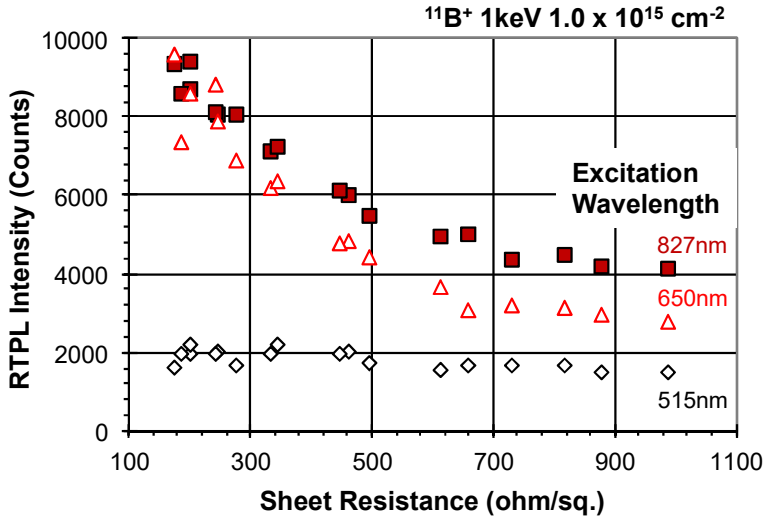

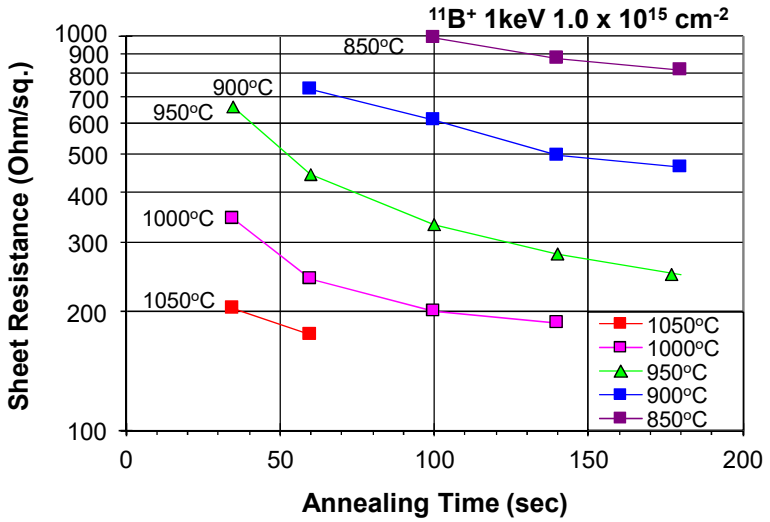

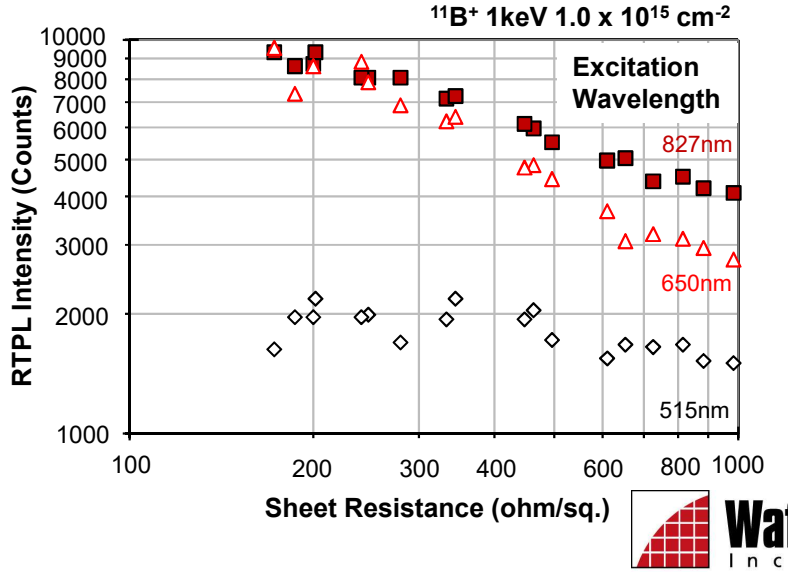

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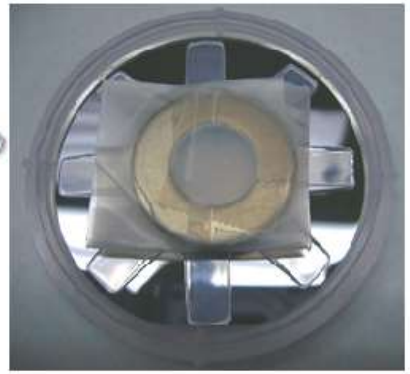
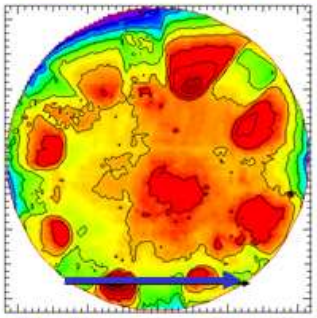
Stress Induced Property Change

(a) As Received
Free Standing in Container

(b) Stressed for 3 days
Tightly Closed Lid with Washer

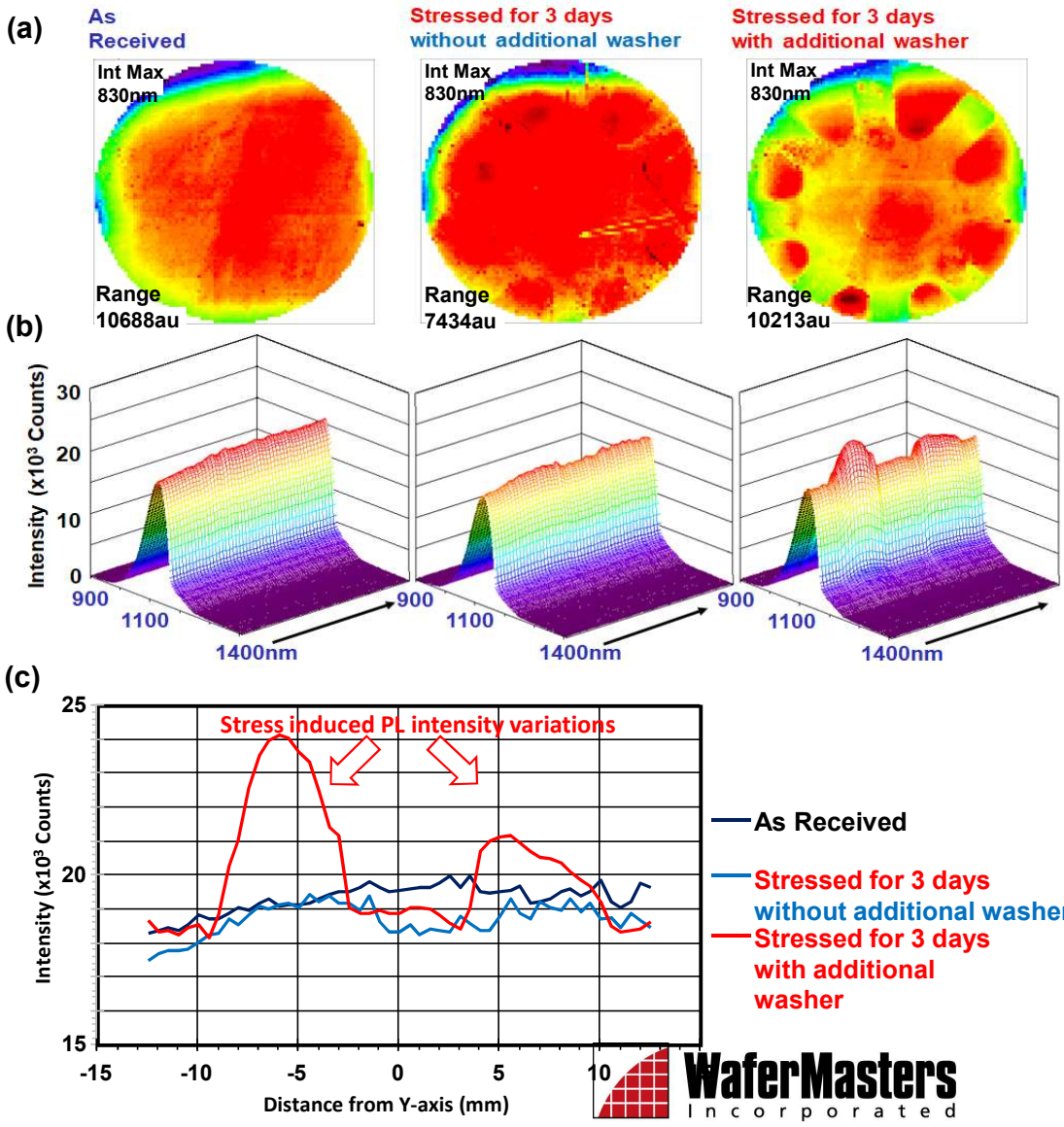


(c) RTPL Mapping & Line Scan Direction



Si Wafer
Diameter: 50 mm
Edge Exclusion: 3 mm
Intervals: 500 μm in X and Y Directions
Measurement Points: >6000 Points
Excitation Wavelength: 830 nm
Exposure Time: 500 ms/point

RTPL Line Scan (51 Points)



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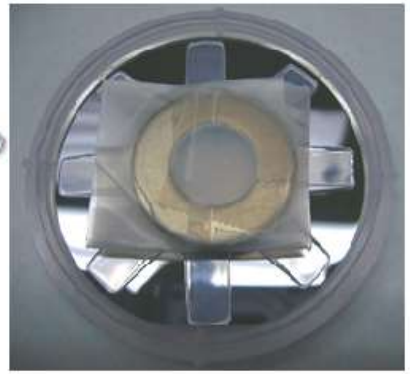

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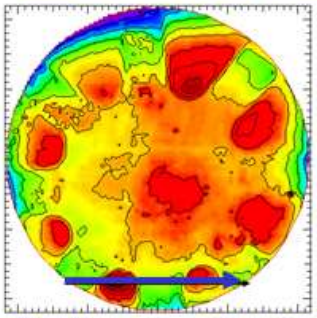

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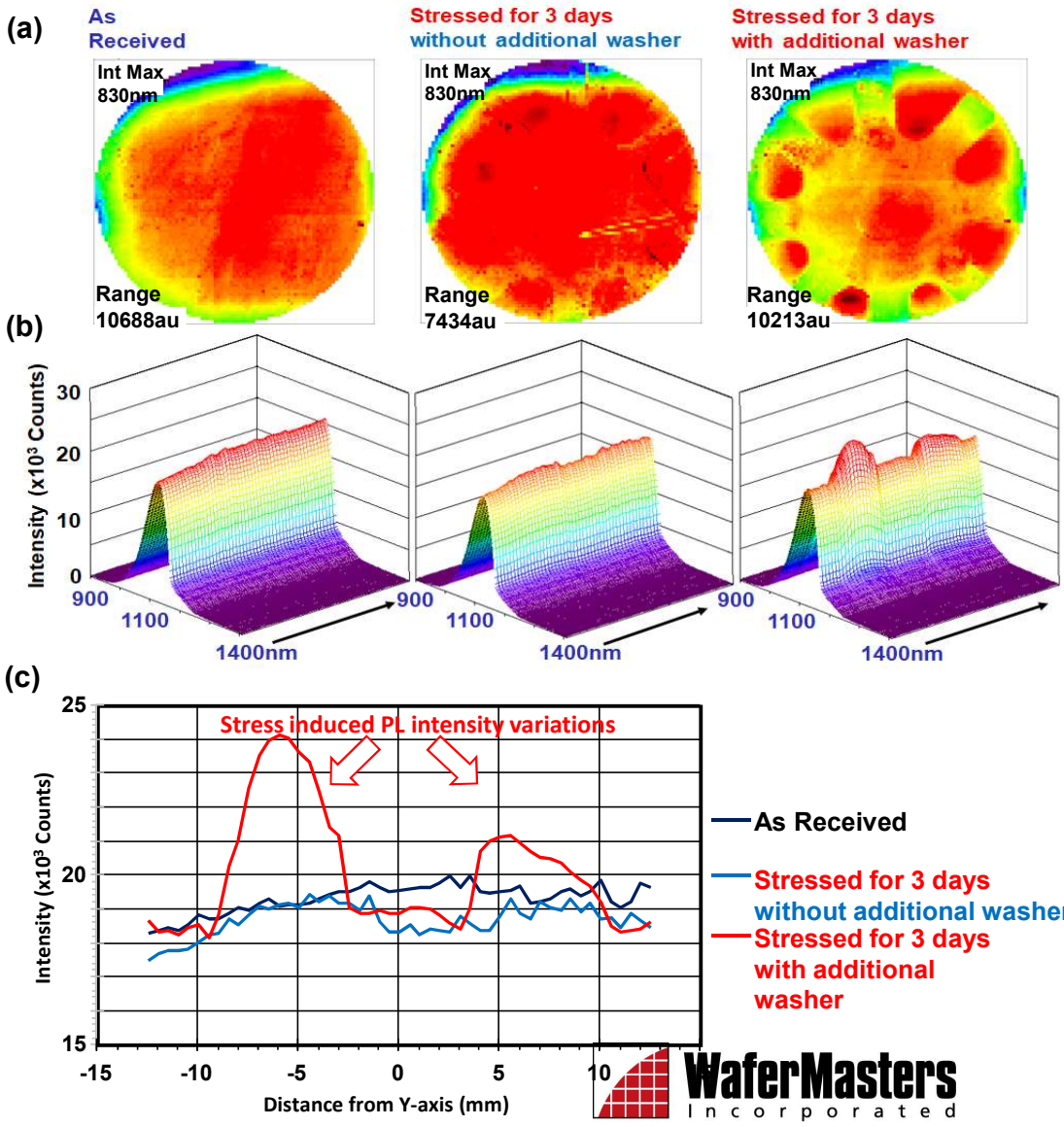

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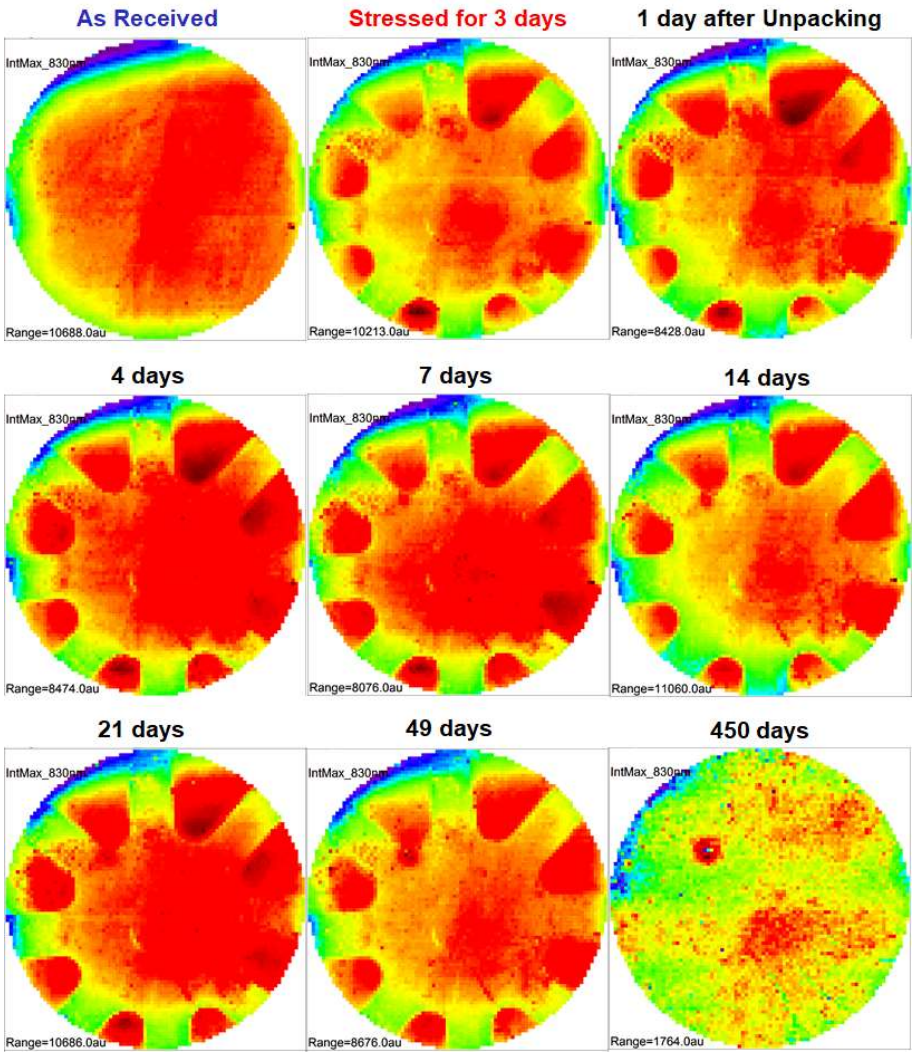
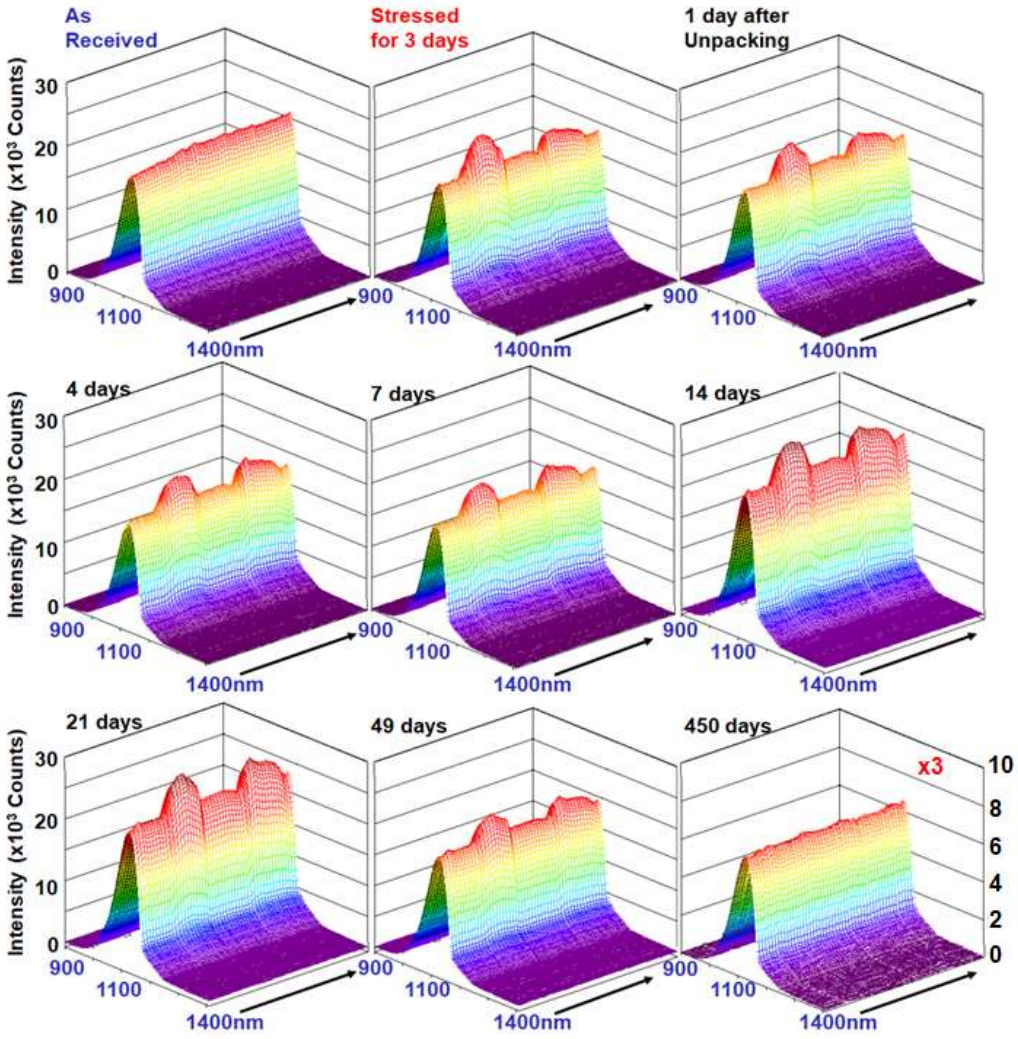
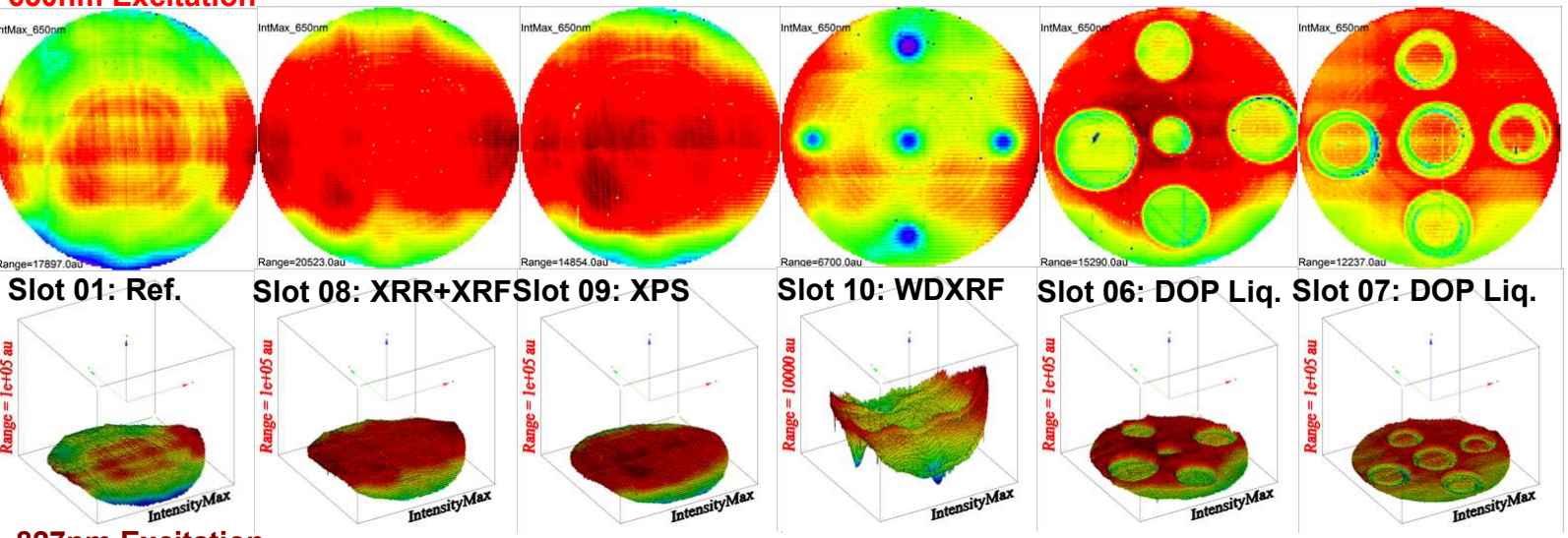


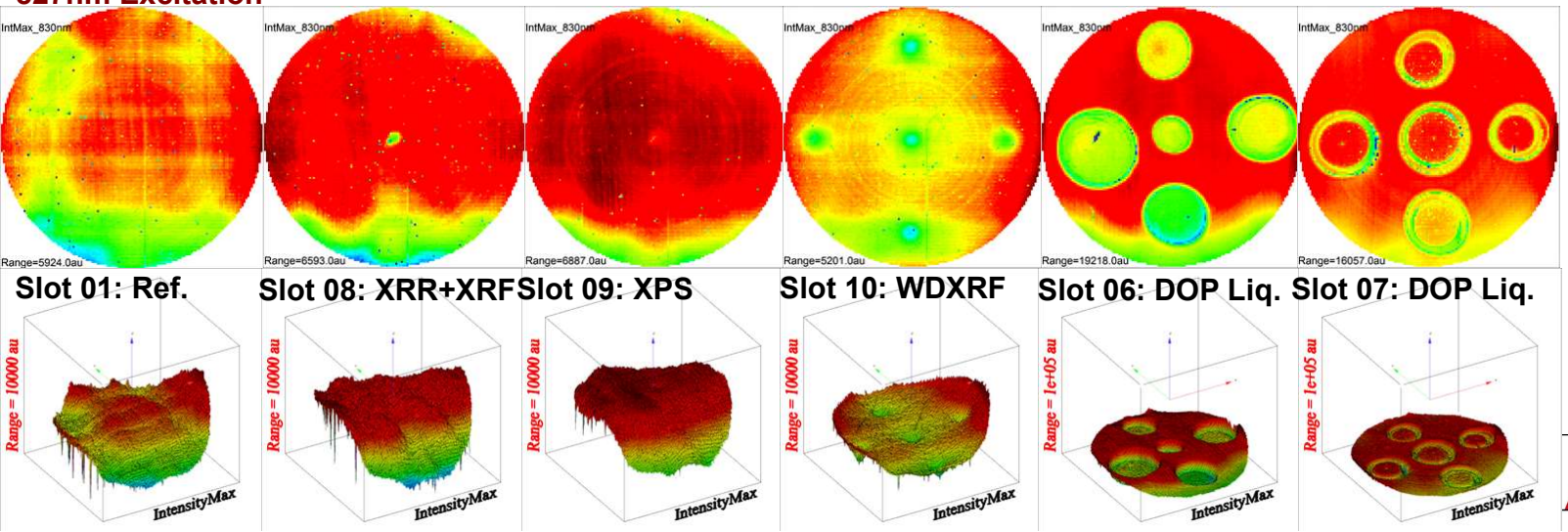


650nm/827nm PL Mapping Results

650nm Excitation



827nm Excitation



Slot 01: Reference Si
Slot 02: DOP Vapor 7 Days
Slot 03: DOP Vapor 7 Days
Slot 04: DOP Vapor 14 Days
Slot 05: DOP Vapor 14 Days
Slot 06: DOP Liquid
Slot 07: DOP Liquid
Slot 08: XRR + XRF
Slot 09: XPS
Slot 10: WDXRF

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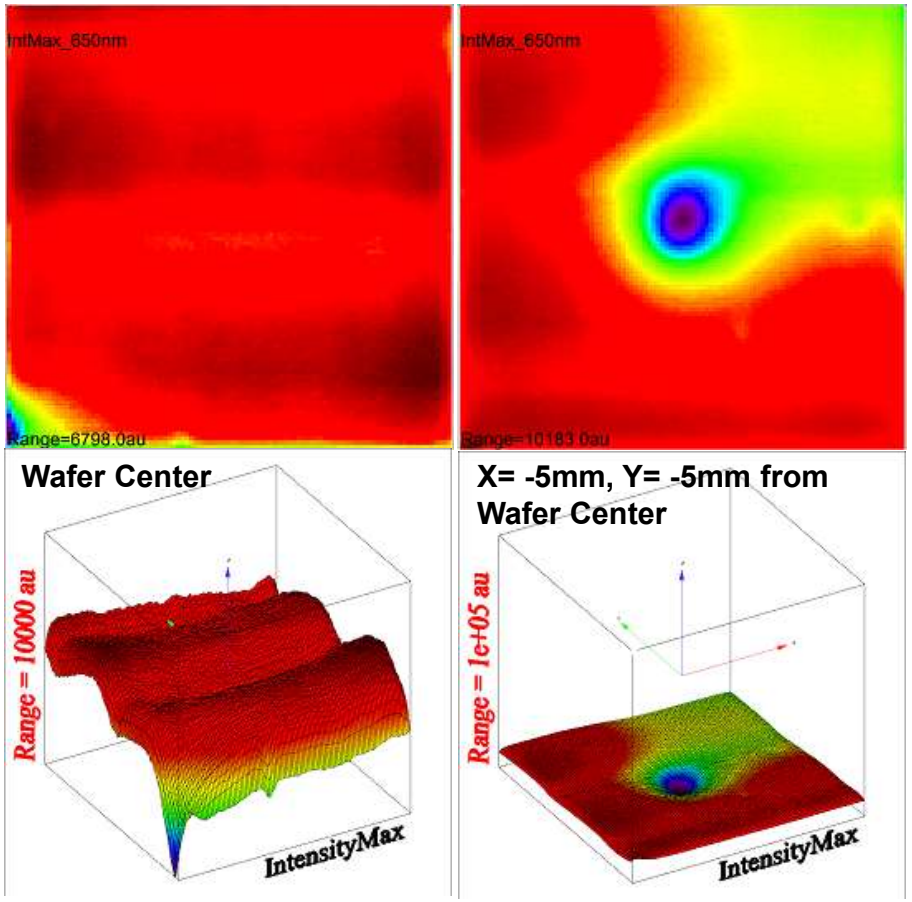
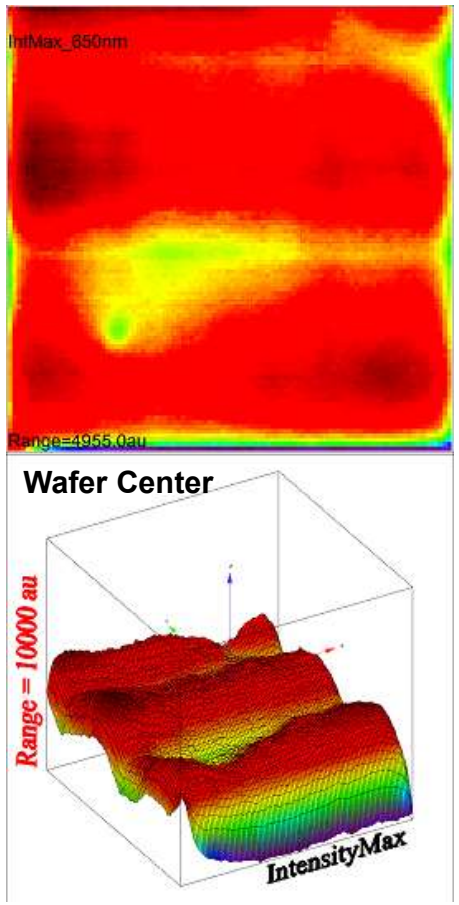
650nm Excitation PL Area Mapping

Slot 08: XRR+XRF



Slot 09: XPS



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Slot 09: XPS
Slot 10: WDXRF

10mm x 10mm in 100um intervals

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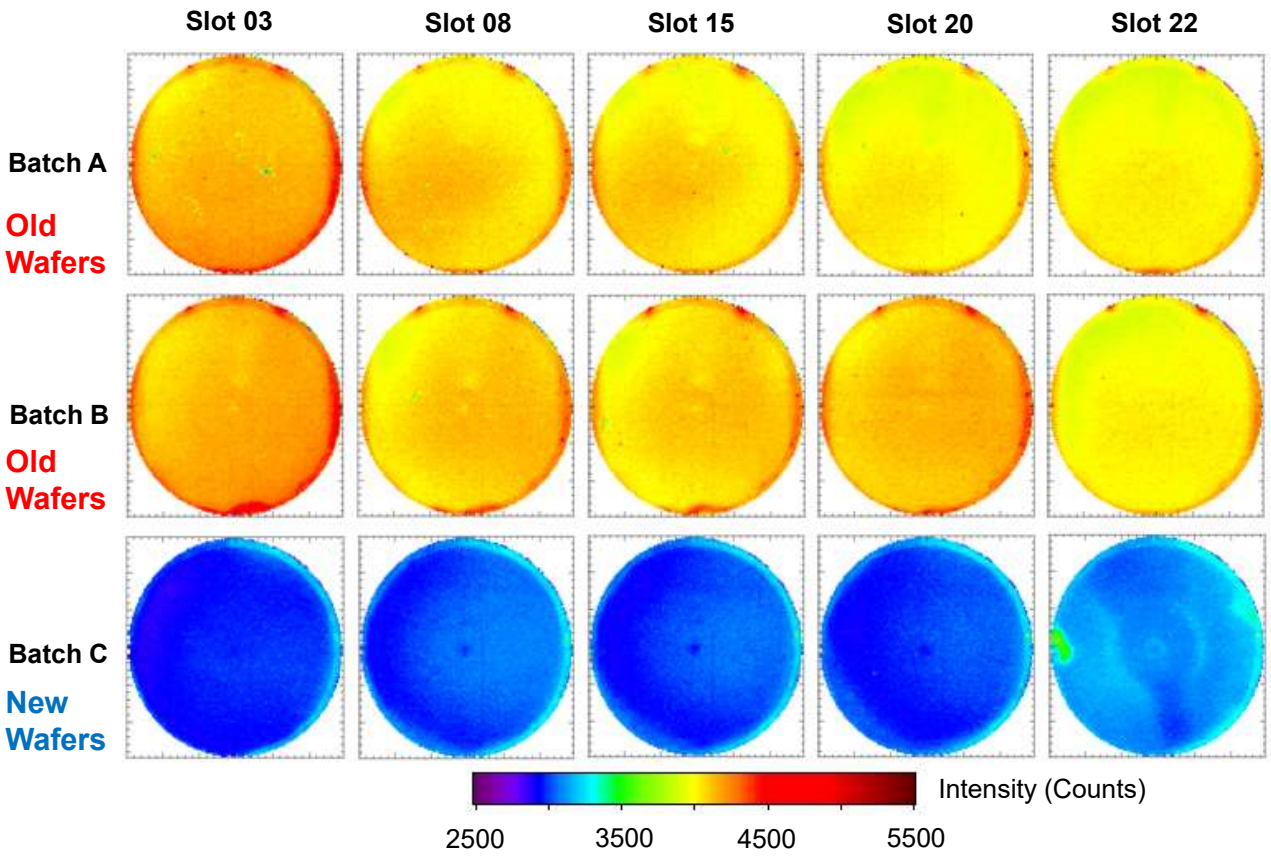
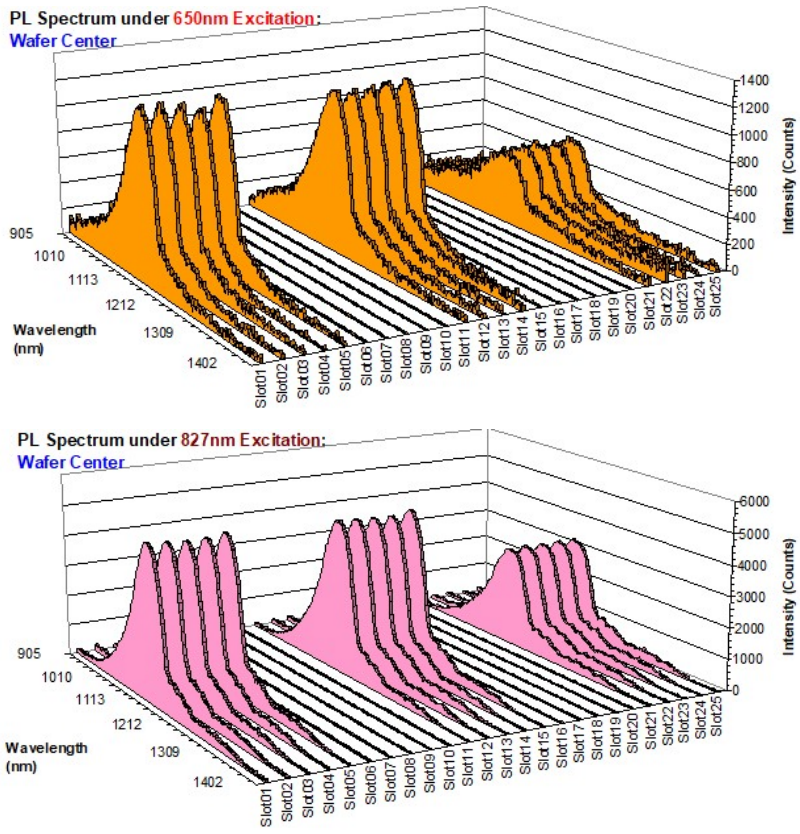
PL Wafer Mapping Results

827nm Excitation RTPL Maps

Exposure: 250 ms





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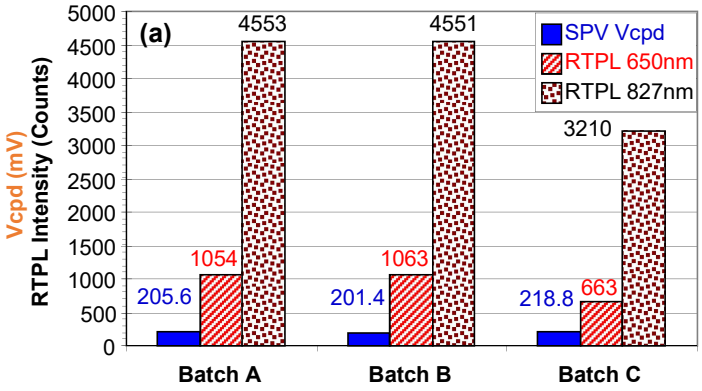
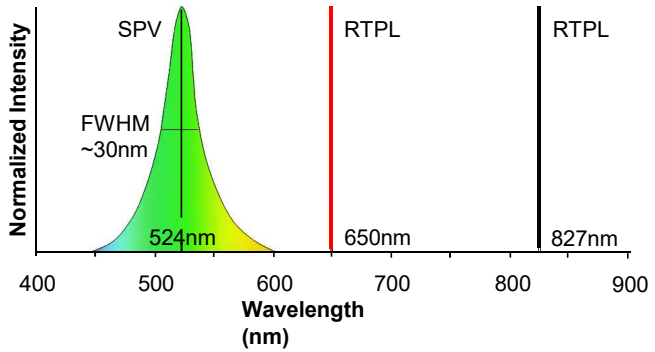
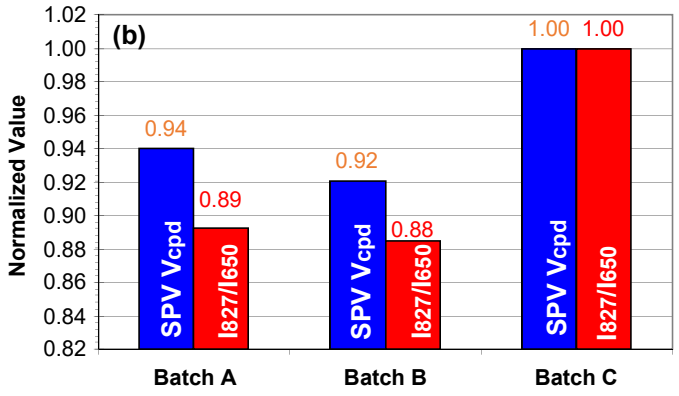
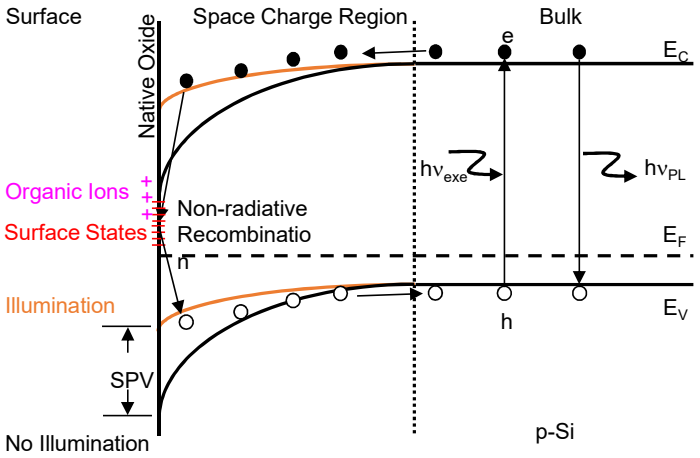
Photoluminescence (PL) vs. Surface Photovoltaic (SPV)









SPV: Poor Sensitivity, Poor Repeatability, Poor Spatial Resolution (~10mm), Mainly for Blanket Wafer Applications

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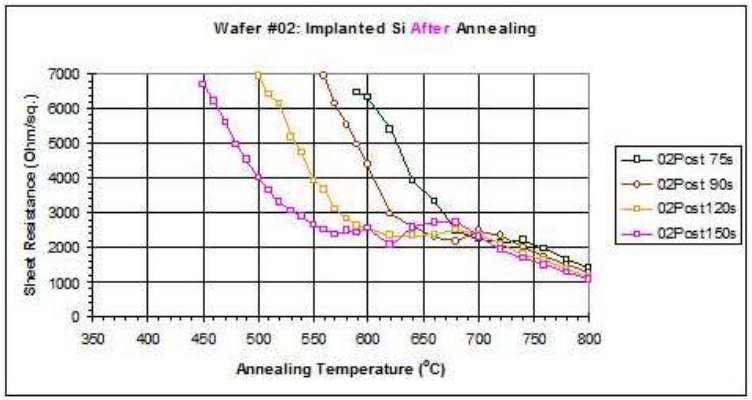
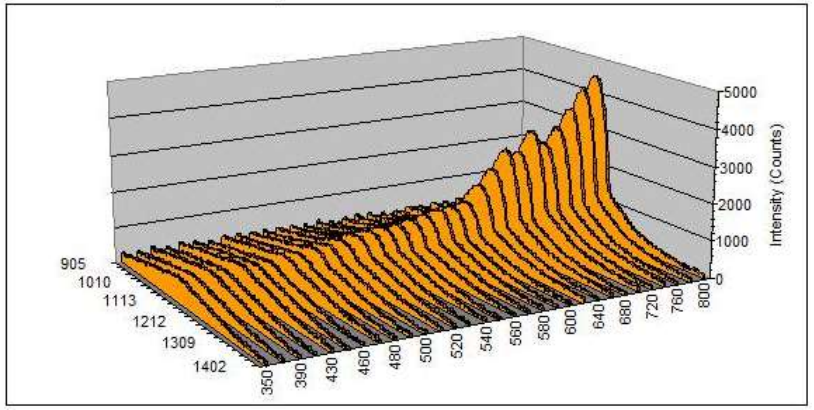
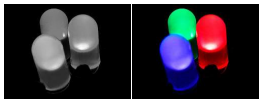
Rs and PL Spectra from Implanted Si after RTA



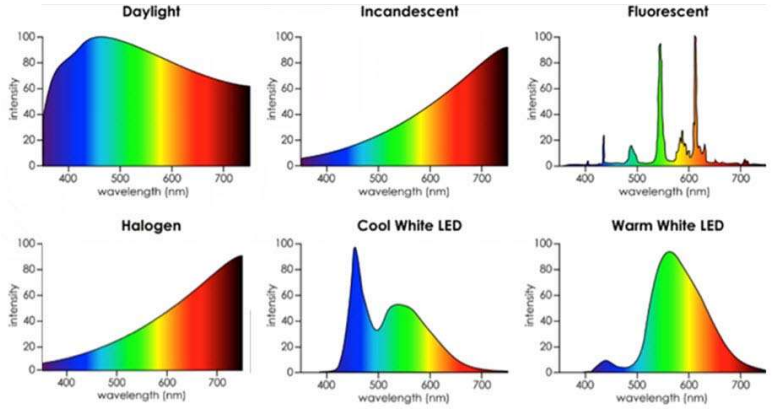
650nm Excitation PL, 500ms Exposure



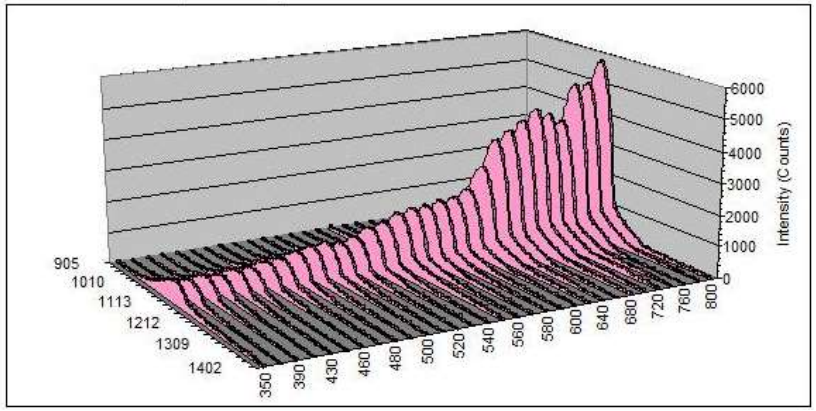


Brightness: Overall Ariel Intensity

Spectra: Intensity Distribution in Wavelength Domain



785nm Excitation PL, 500ms Exposure



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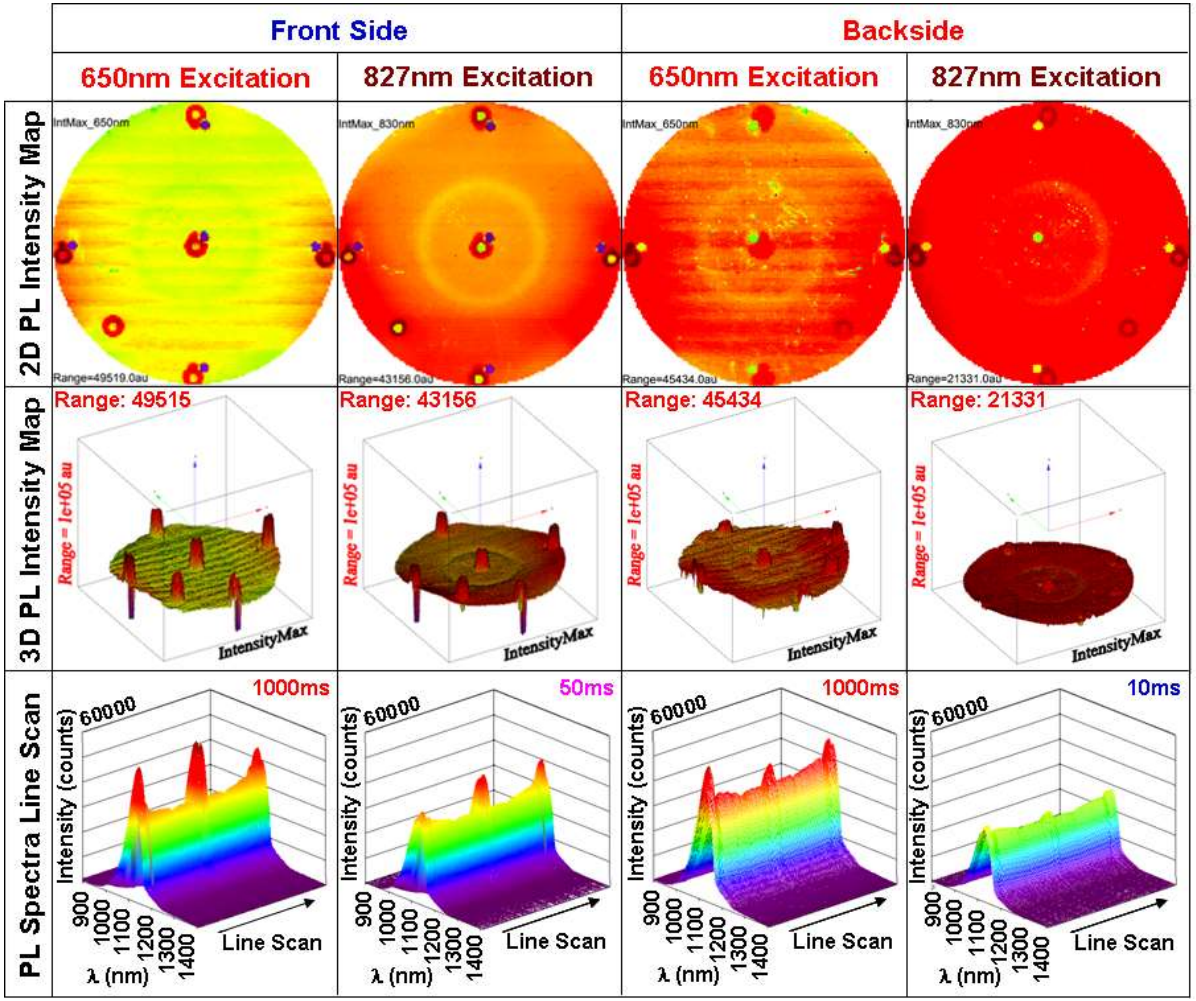
Multiwavelength PL Mapping Results
after Non-contact Corona-based C-V and I-V Measurements



C-V and I-V
Measurement Signatures

Evidence for
Destructive Characterization

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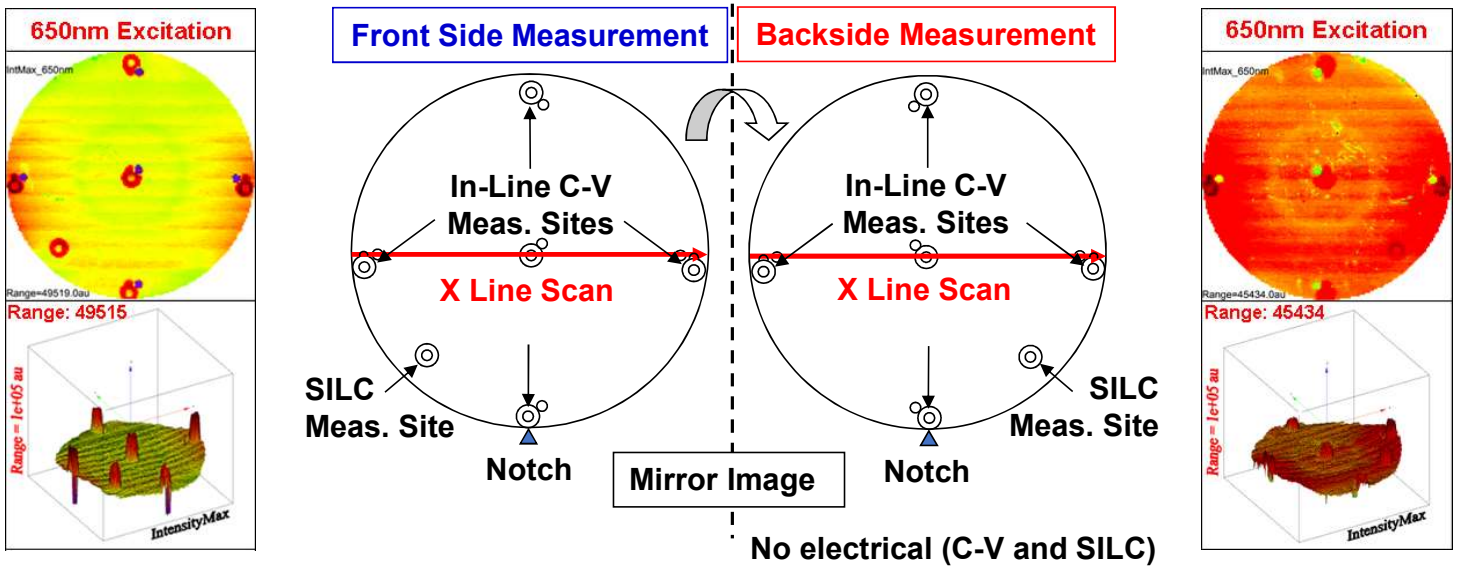
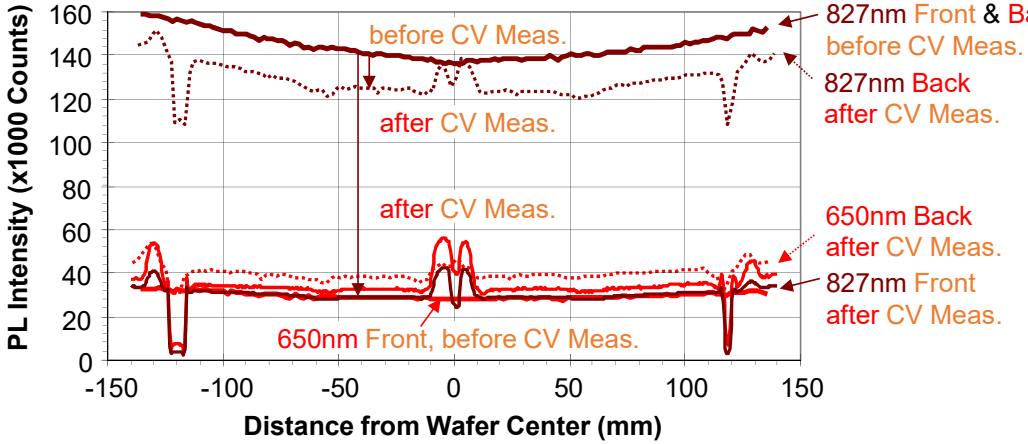
Multiwavelength PL Mapping Results
after C-V and I-V Measurements





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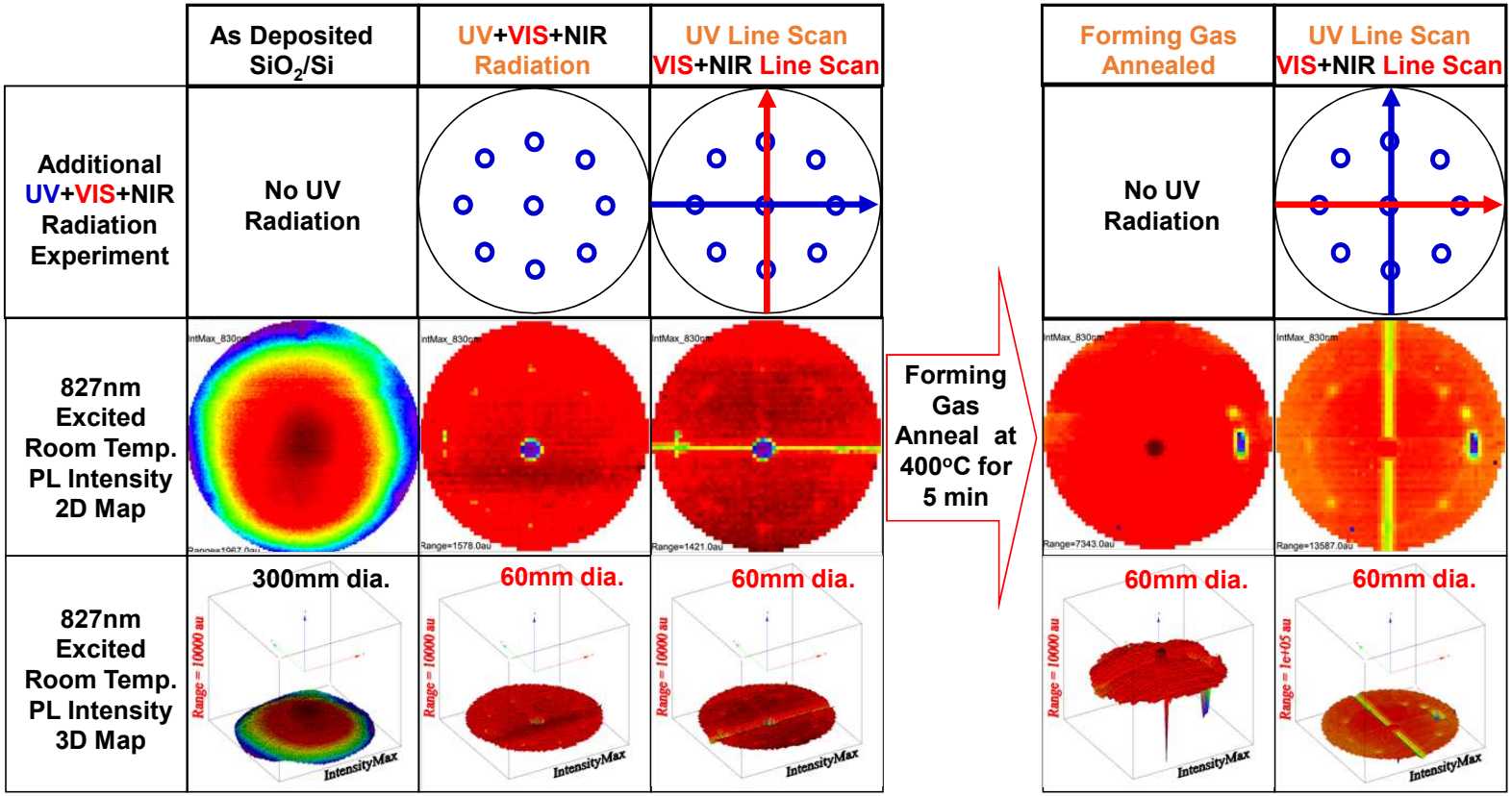
Multiwavelength PL Mapping Results
after UV-Based Film Thickness Measurements



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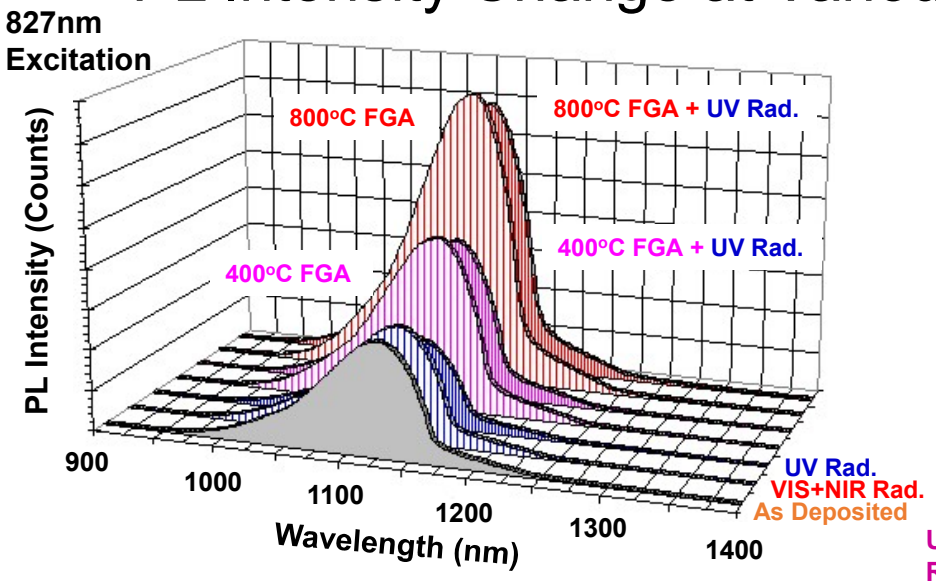
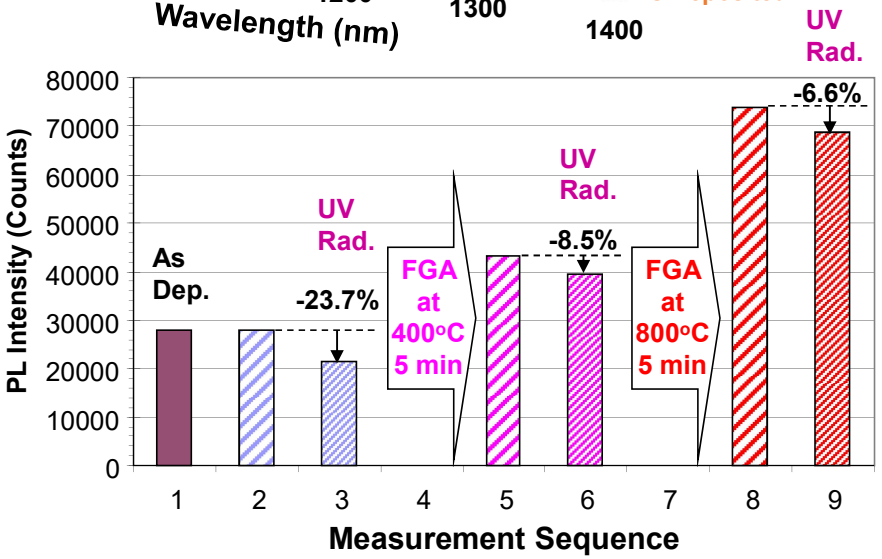
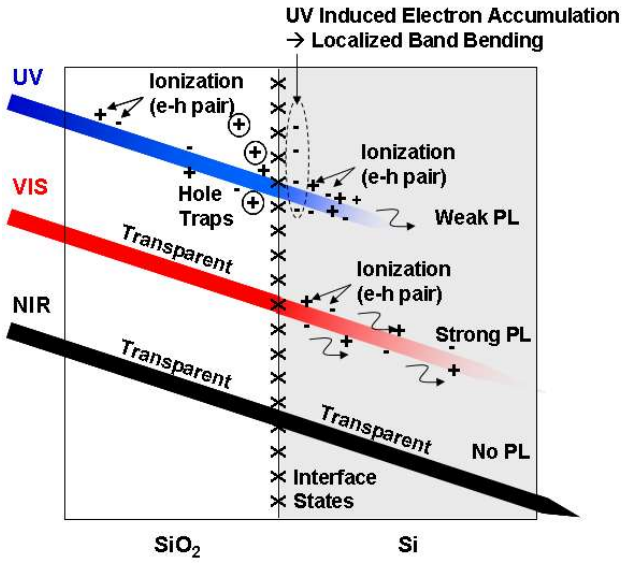
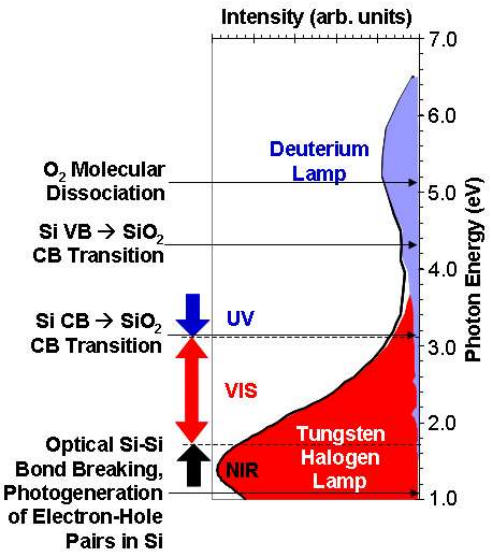
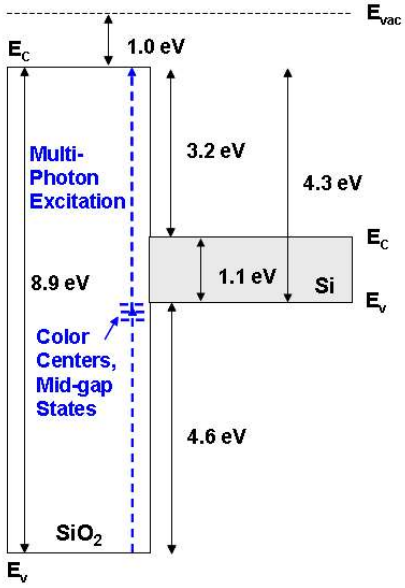
PL Intensity Change at Various Stages





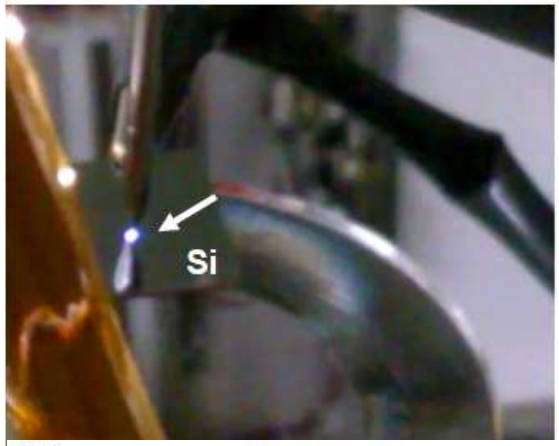






Properties of Native Oxide/Si Interface after Electrical Breakdown

(a) HVDC Arc
2000V DC, ~1000 ms



(b) Piezo Ignition Arc
~4000V Pulse, ~1 ms