VOC & Metallic Contaminant Control For SOI Process Monitoring

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Introduction:
Nanotechnology, SOI and Soitec

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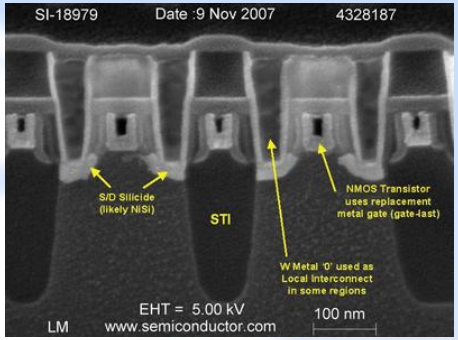
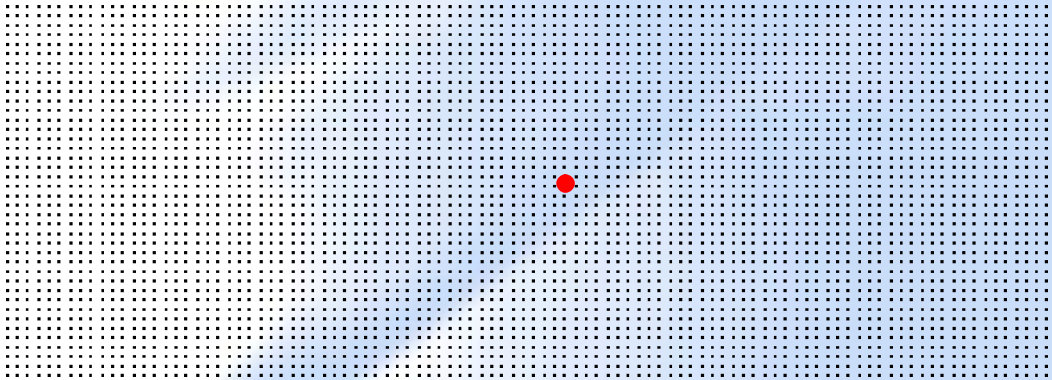
Nanoscale: Not Just Feature Length

Nanoscale usually refers to the lengths of features…



45nm NMOS Transistor Cross Section
High-k Dielectric and Metal Gates

…but nanoscale variations in surface condition are critical to manufacturing yield



1 contaminant atom in 4000 on surface = 1.7 X 10^{11} atoms/cm^2
(Density of Surface Atoms on <100> Si Surface is 6.78 X 10^{14} atoms/cm^2)

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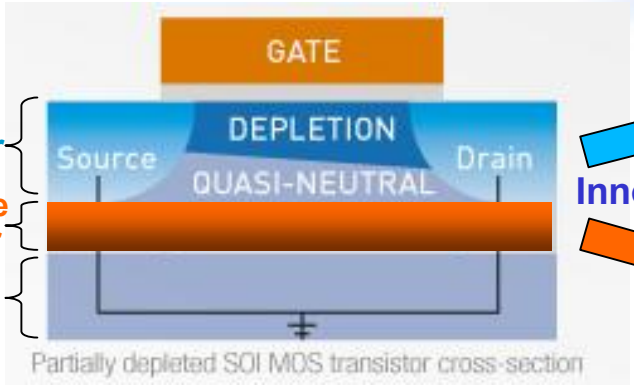
Nanotechnology Commercialization

- **Nanotechnology involves the introduction of significant new materials, structures, and processes**
- **Nanotechnology requires the ability to inspect and control nanoscale characteristics of surfaces over larger-scale areas**
  - **Metal, organic, and inorganic contamination**
  - **Film uniformity**
  - **Surface chemistry**
  - **Atomic scale surface defects/reconstruction**
  - **Surface and dielectric charging**

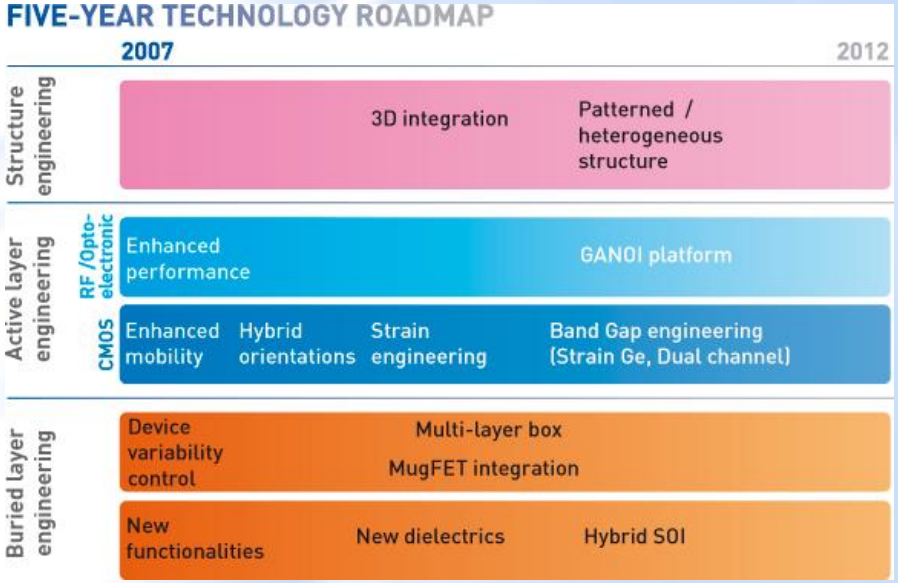
SOI and Nanotechnology

The Soitec Group's mission is to innovate and industrialize advanced engineered substrates for mobile, high-performance and advanced microelectronic applications.

SmartCut **SOI Technology**



Innovation



EC €200 Million NanoSmart Program

The NanoSmart project will expand the Smart Cut "toolbox" into further silicon-related advances, as well as into other materials, particularly in the III-V arena.

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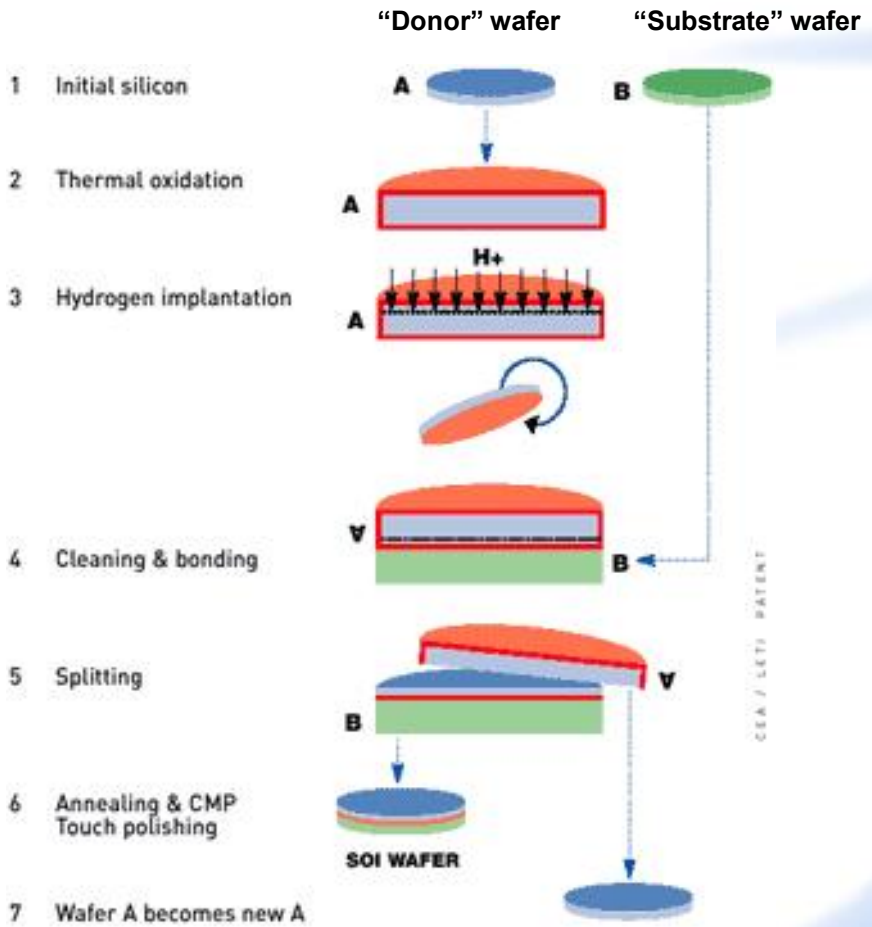
Soitec SmartCut Process

SmartCut Technology



- A buried oxide (BOX) layer is grown atop a Donor Wafer, then this wafer is bonded to a Substrate Wafer
- The Donor Wafer is then split away, leaving the Substrate wafer with the BOX layer and a thin Si layer from the Donor
- Impurities or nonuniformities at any step of the process leads to unacceptable defectivity in the final SOI wafer

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ChemetriQ Operating Principles

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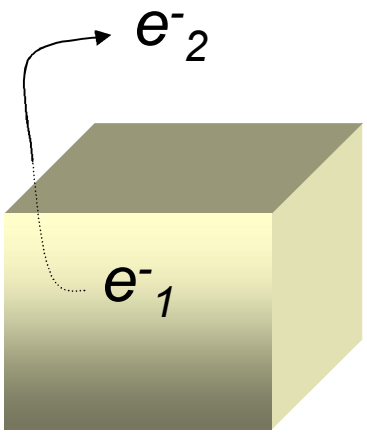
What are Non-Visual Defects (NVDs)?

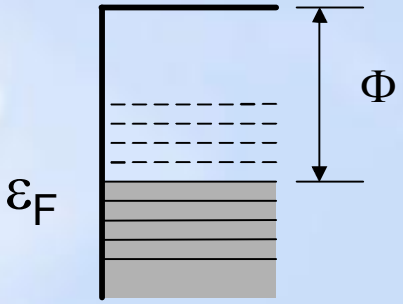
- NVDs do not scatter light and therefore are not detectable using traditional optical inspection tools
- NVDs include:
  - Organic residues
  - Metallic residues
  - Watermarks
  - Process induced charge
- Residues are often less than a monolayer (submonolayer)
- NVDs, like physical defects are yield impacting
- Cleaning and surface preparation are the most repeated steps in the fab
- New NVDs are arising from new cleans, new materials, and tighter specs

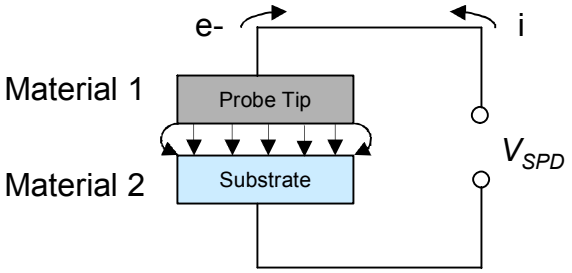
ChemetriQ Operating Principle:
Fundamentals Based on Work Function Measurement

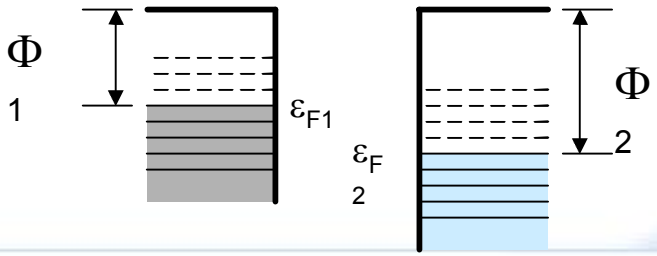


Work Function

the energy (Φ) required to remove an electron from a material's Fermi level (ε_F) to a non-interacting point outside the solid (material).







Surface Potential Difference (SPD)

a method to measure the difference in work function between two materials that are in close proximity and electrically connected.

$$V_{SPD} \sim (\Phi_2 - \Phi_1).$$

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ChemetriQ Operating Principle:

ChemetriQ Incorporates Differential Work Function Inspection

The ChemetriQ Inspection system utilizes a scanning surface potential difference system that detects changes in materials and charge on the wafer surface.

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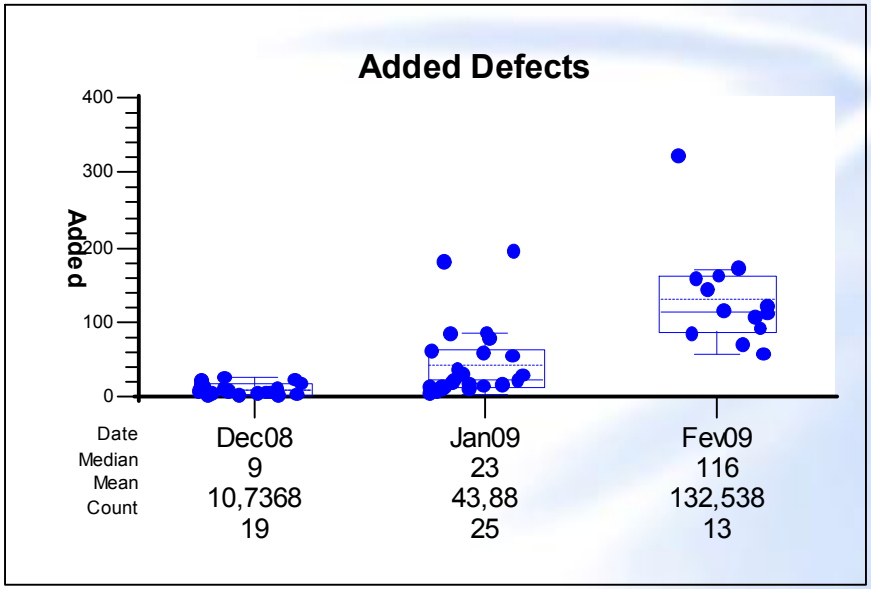
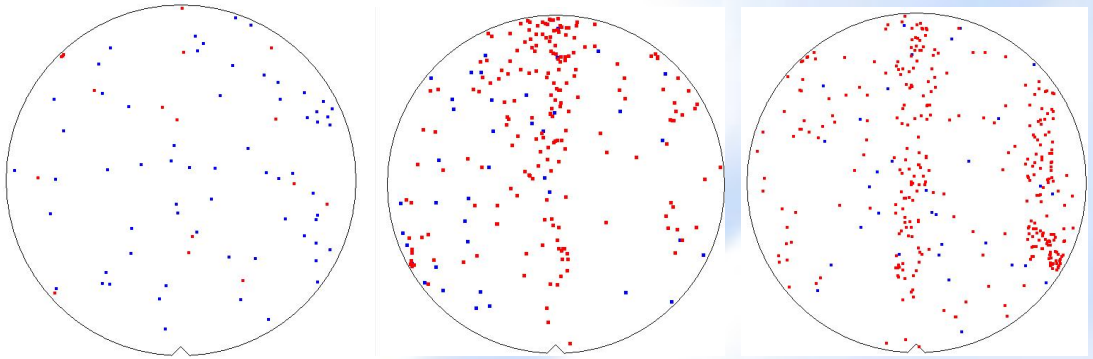
Process Problem:
Increasing Particle Trend after a Wet Clean Step

Problem Description – Increasing Particle Defects

- **50 nm particle levels were increasing after a particular in-line cleaning step**



GOAL : understand the root cause !



Dec 08
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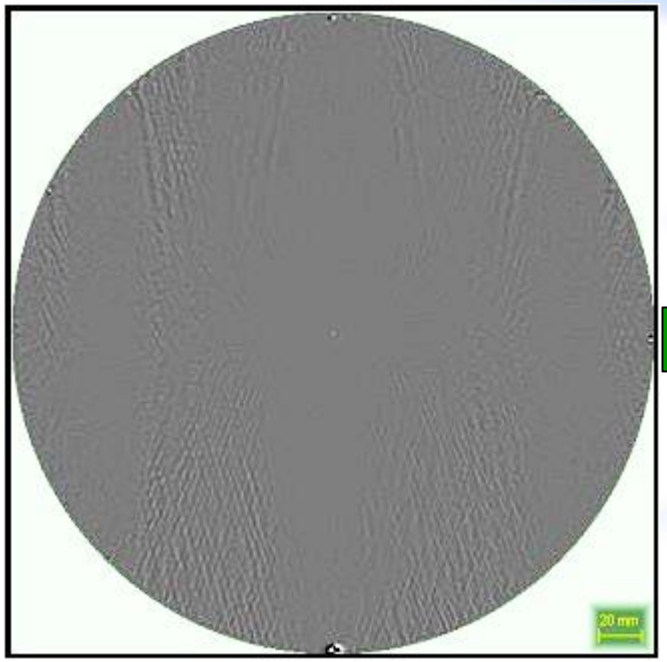
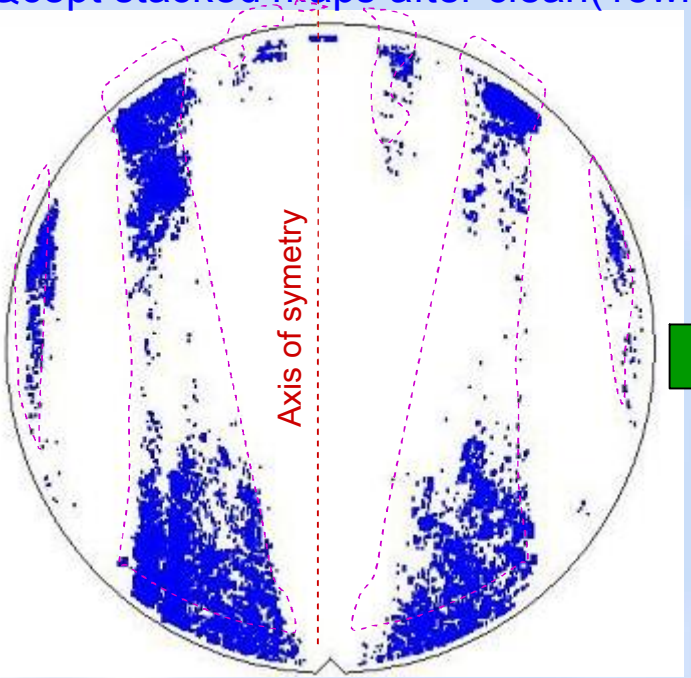
The ChemetriQ is used to understand defectivity origin

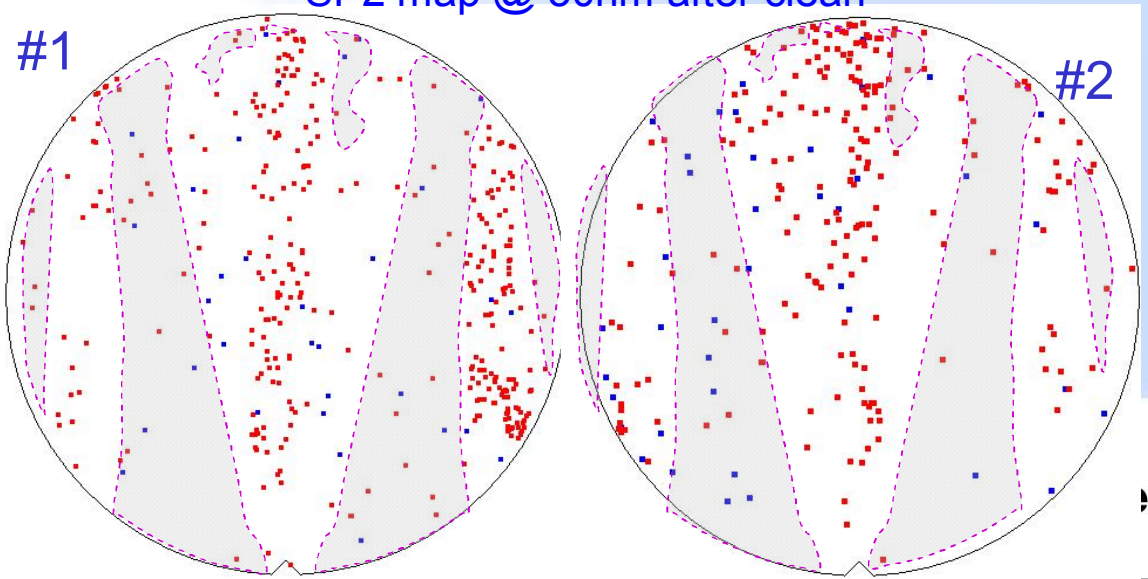
Qcept map after clean :



Qcept stacked maps after clean(18wfrs)

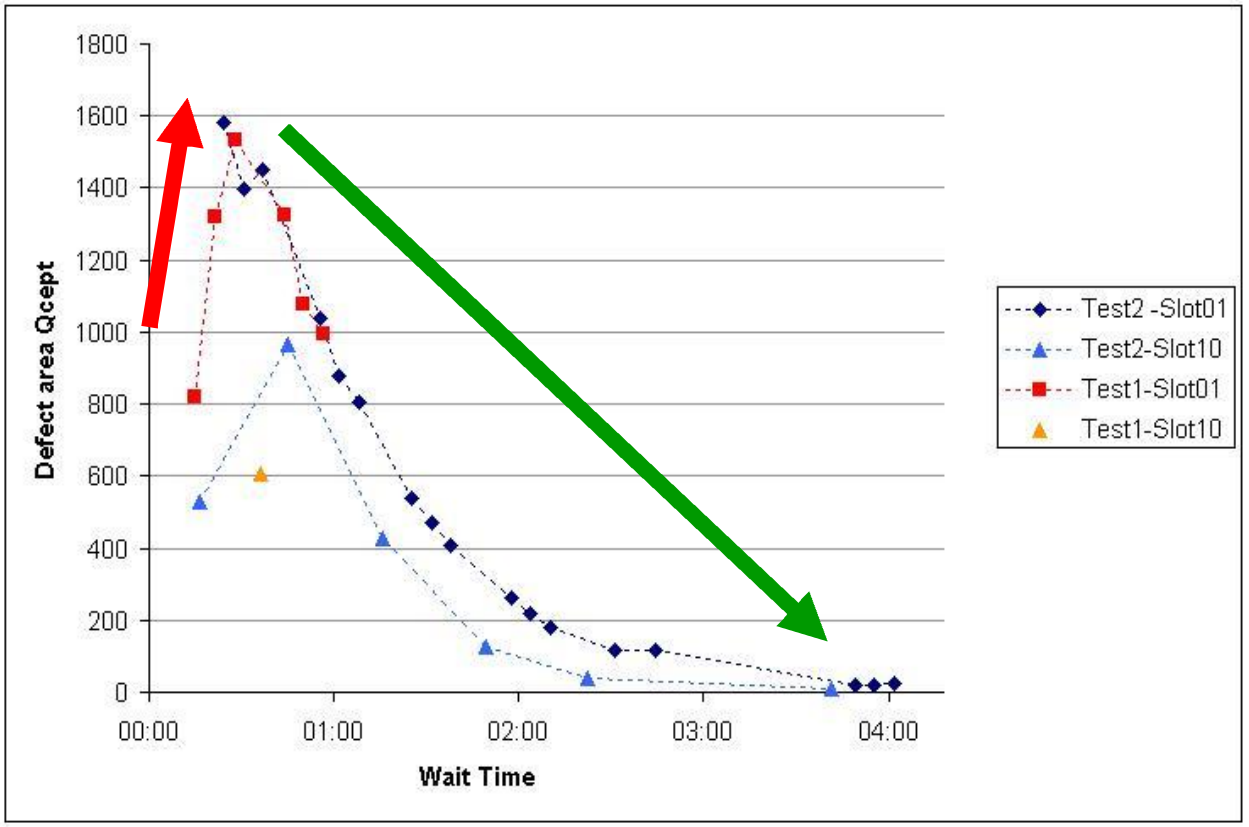


SP2 map @ 50nm after clean



QCEPT pattern matches with particle defectivity seen at 50nm !!

Understanding the Phenomenon



Phase 1 : water layer is uniform; during evaporating water film becomes fragmented; increasing QCEPT defectivity.

Phase 2 : water continues to evaporate until disappearing, returning QCEPT defectivity near 0.

- **Defective Area increases at first and then decreases with time**
- **Hypothesis: The ChemetriQ is detecting water on the wafer surface**

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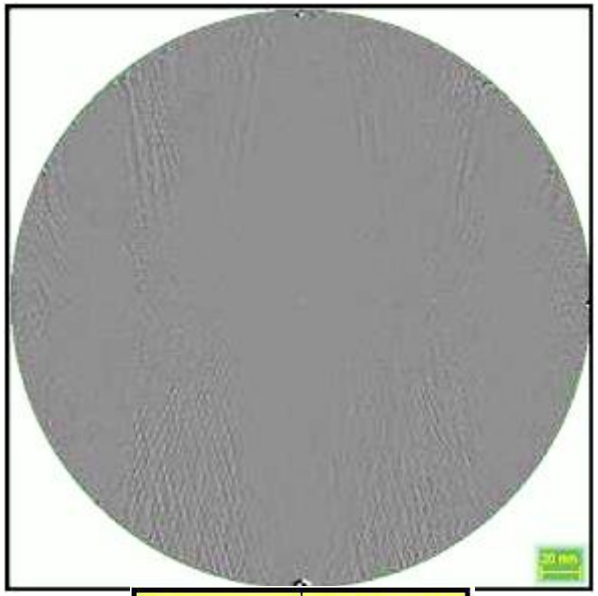
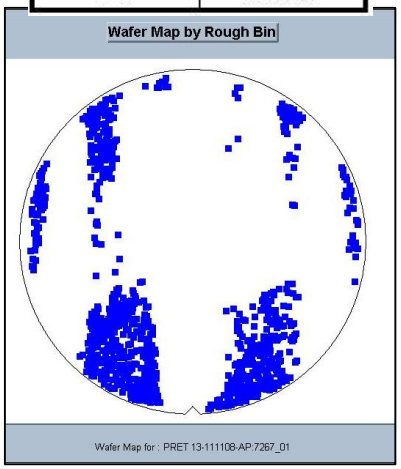
Understanding the Phenomenon (cont'd)

Time ≈ 1 hour



Defect count	Defect area
863	2179.8



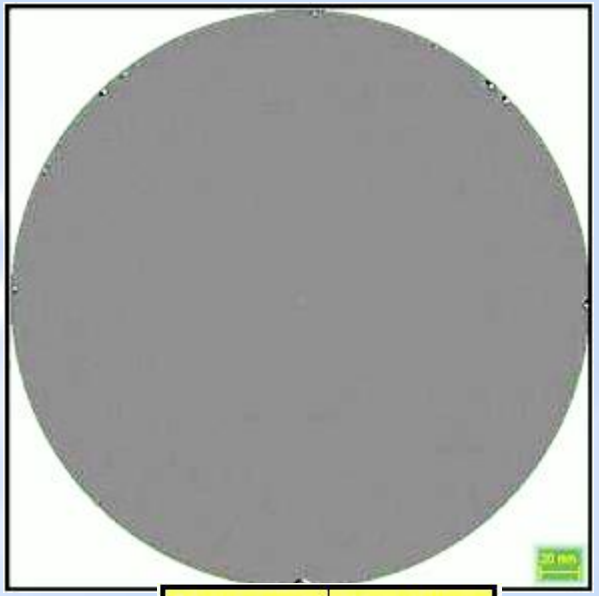
Pattern intensity seen by QCEPT immediately after cleaning increases during the 1st hour then decreases to zero after ~4hours

→

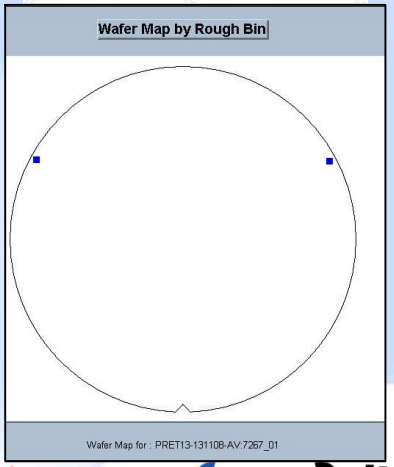
The corresponding defect maps show the decrease in defect counts after 4 hours

→

Time ≈ 4 hour



Defect count	Defect area
2	4.7



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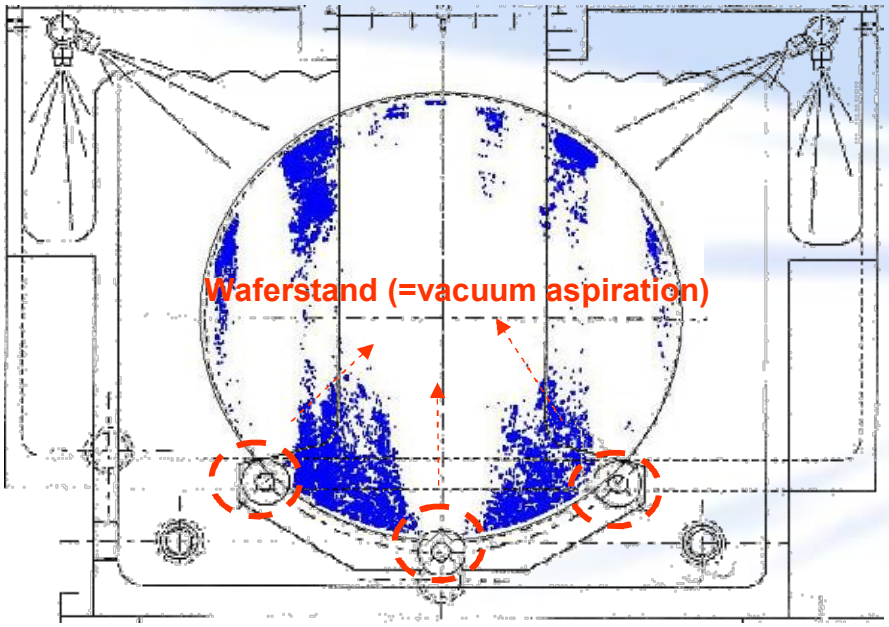
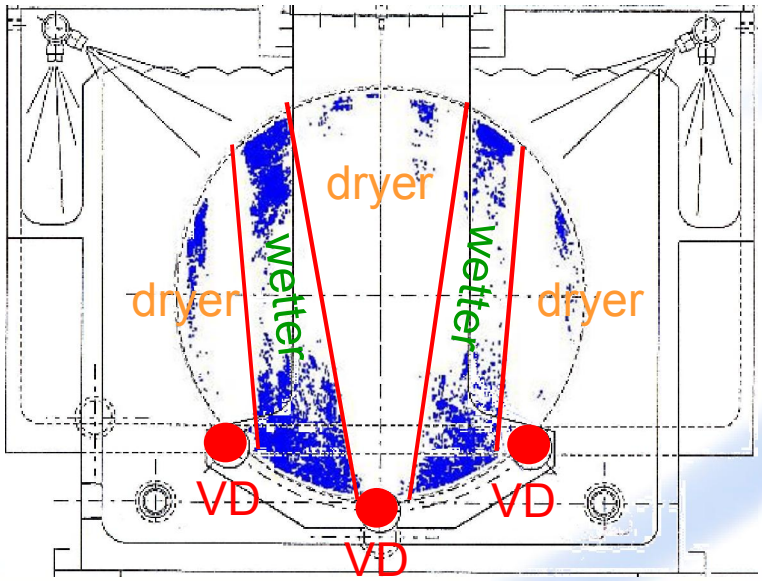
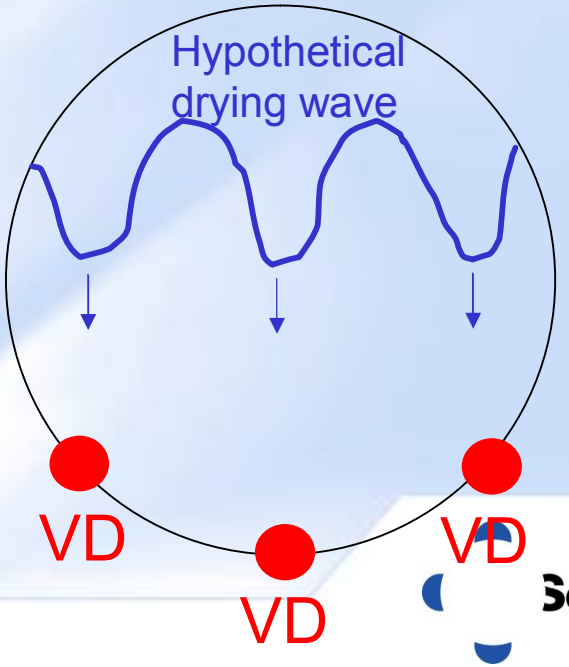
Link with cleaning tool :





ROOT CAUSE :

- QCEPT pattern seems to be correlated with waferstand & VD (vacuum dry) position
- Area where the drying is faster allows particles to deposit on the wafer
- Corrective action has begun



VD = Vacuum Dry

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Process Problem:
Backside Chuck Contamination Defect Sourcing

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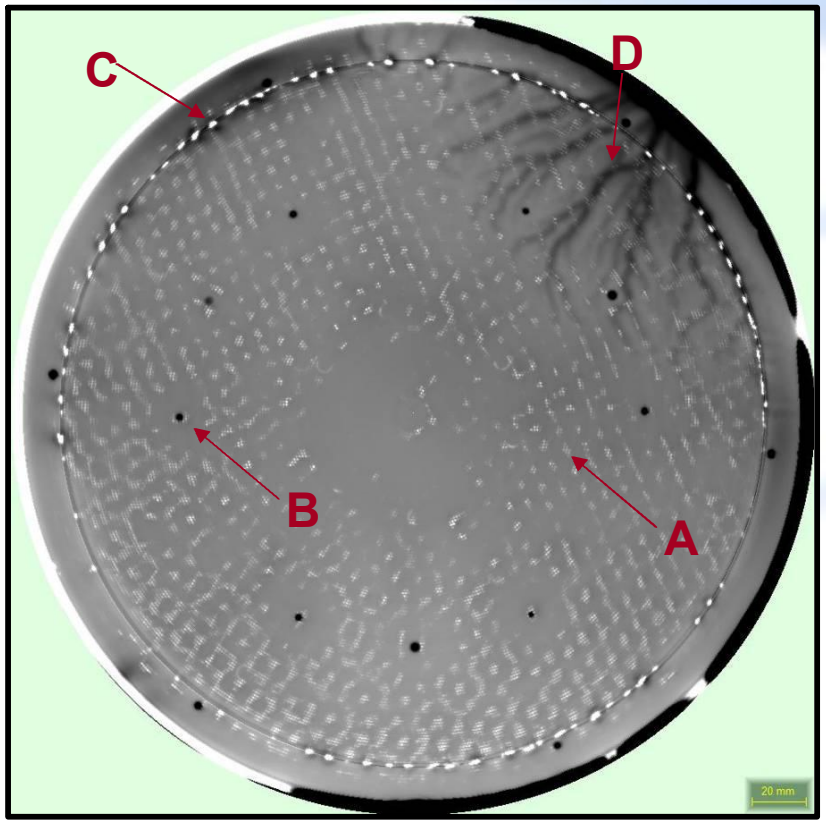
Backside Al Contamination

VPD-ICPMS showed Al contamination at 1.2E10 atoms/cm2



- A particular metrology tool was causing backside Aluminum contamination
- The chuck was suspected and was cleaned many times and the vendor was designing a lower contact chuck
- The image at the left is a ChemetriQ integrated image from a wafer that was placed on the chuck of the metrology tool
- There are 4 distinct regions:
  - Chuck signature (A)
  - Lifter pin signature (B)
  - Electrostatic Ring signature (C)
  - “Dendrite” region (D)

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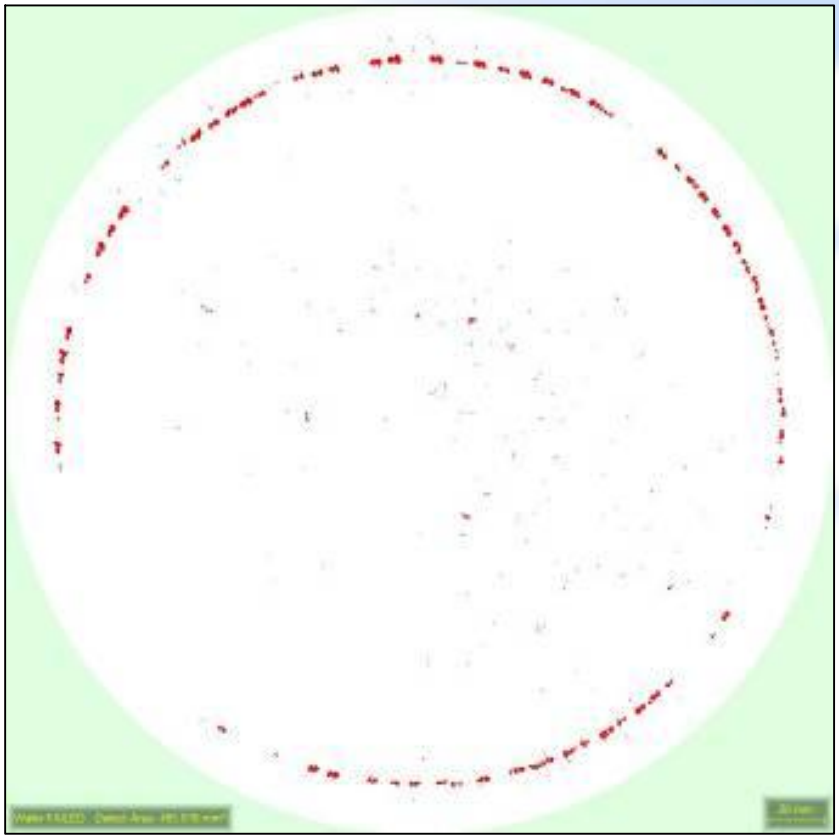
Trace Metals – Backside Al Contamination

ChemetriQ Spatial Signature Provided Critical Piece of Knowledge to Al Source



- Positive work function (+WF) defects are generally metallic and negative work function (-WF) defects are generally organic
- So the integrated image was thresholded for +WF defects only
- The resultant defect map showed that the strongest defects were in a ring near the edge of the wafer and not in the center of the wafer from the chuck
- This signature led us to perform TOF-SIMS at the ring signature

The defect map showed that the outer ring was likely the primary source of contamination and not the chuck signature

Trace Metals – Backside Al Contamination

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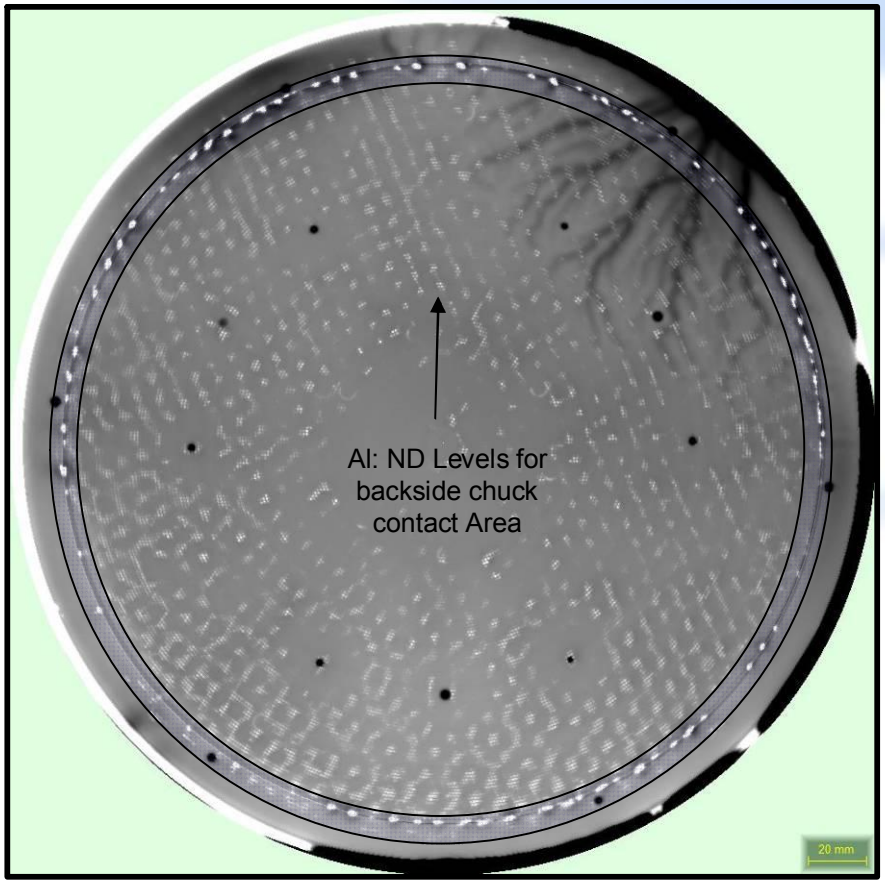

Al: ~5E11 atoms/cm^2

Area Adjusted TOF-SIMS:
1.18E10 atoms/cm^2

VPD/ICPMS:
1.20E10 atoms/cm^2

- The outer ring was analyzed using a TOF-SIMS to identify the element
- Interior reference points of the chuck touch points were also selected with no detectable levels of Al (<1E8)
- The outer ring analysis showed an average level of Al contamination at the 5E11 range, with a maximum reading of 6E12 atoms/cm2
- The outer ring concentration, when adjusted for area, matched the level of Al from the VPD ICPMS testing
- The proper spatial information provided by the ChemetriQ analysis allowed us to focus on the true source of the contamination

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Process Problem:
Yield Failure at Final SOI

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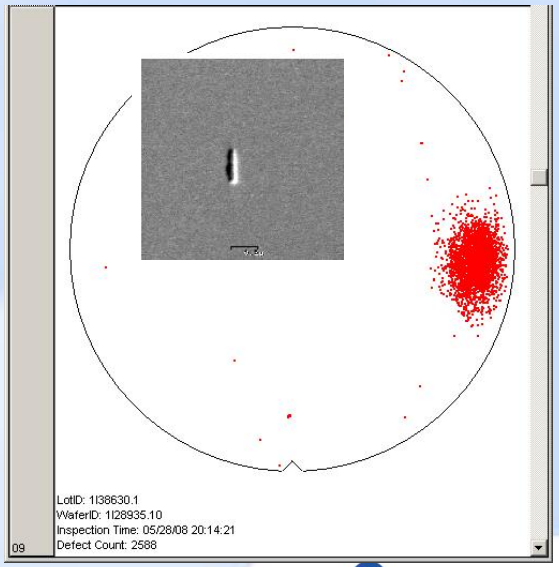
Problem Description – Yield Failure at Final SOI

- Some SOI wafers were experiencing a yield killing defect at final inspection
- This defect was a group of small gouges at the surface located predominately near the 3 o'clock position on the wafer
- Traditional inspection techniques could find this defect only at final inspection
- The root cause was isolated to a metrology tool that inspected at a step prior to the oxidation step
- An inspection was needed to detect this defect at the current process step



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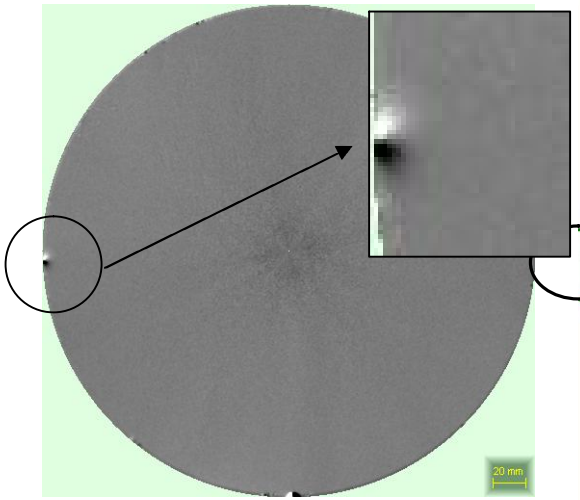
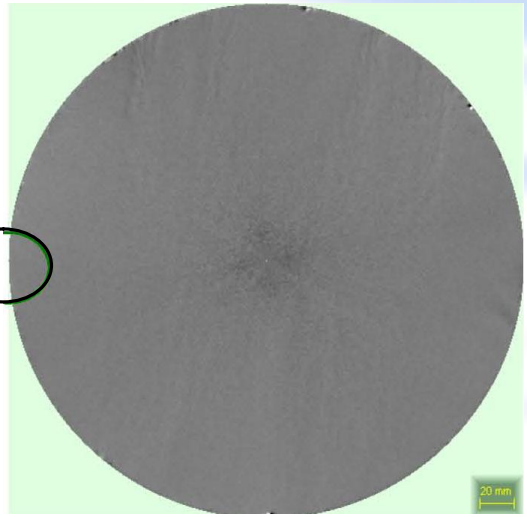
Problem Description – Yield Failure at Final SOI

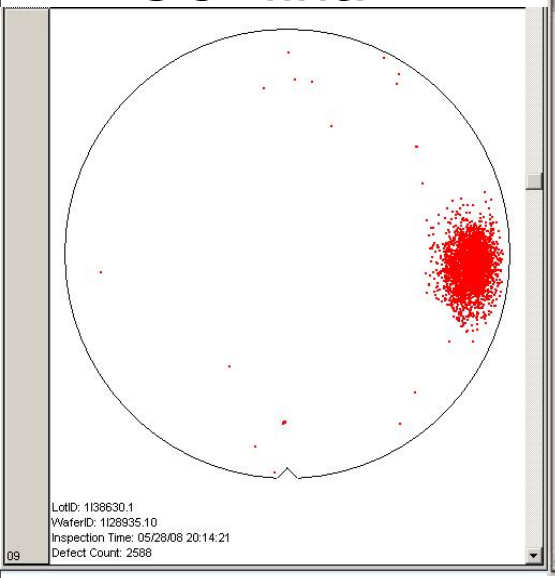
Bad Wafer



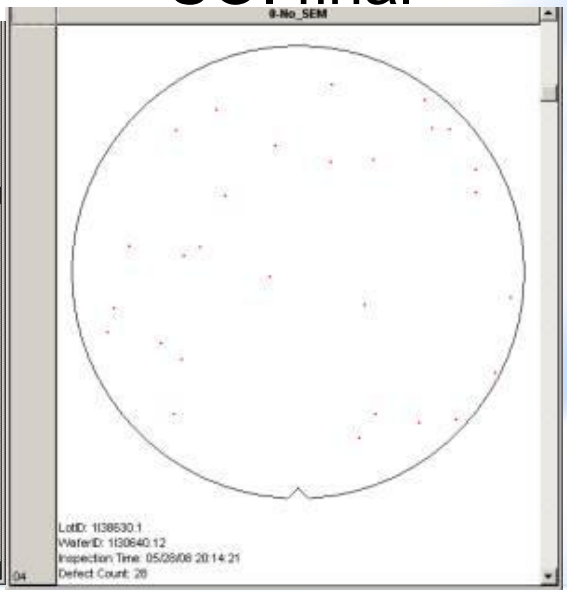
Good Wafer



SOI final



SOI final



- The circled defect on the left is a metallic defect at the very near edge of the wafer
- This matches a touch point from the metrology tool
- This defect at the 9 o'clock position on the SOI donor wafer is the cause of the yield killing defect at 3 o'clock on the final SOI wafer. The donor wafer is flipped and bonded to the base wafer
- A ChemetriQ inspection is now in place as a tool monitor of this metrology tool

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Conclusions

Conclusions

- Nanotechnology requires a greater understanding of the surface conditions in order to ensure yield
- In this paper, we presented results using a novel inspection focused on scanning work function
- These results provided the ability to better control the surface of the wafer, and thus, improve yields
  - Detection of metallic contamination at the wafer edge
  - Detection of nonuniform drying leading to particulate issues
  - Detection of backside metallic contamination signature
- As new processes, new materials and new structures are being introduced, a stronger emphasis on surface inspection will be a requirement