Candela 8520

Integrated Surface + PL Inspection Solution for Power Device Applications

May 2019

Company Overview
Candela Overview
Power Device Use-Cases

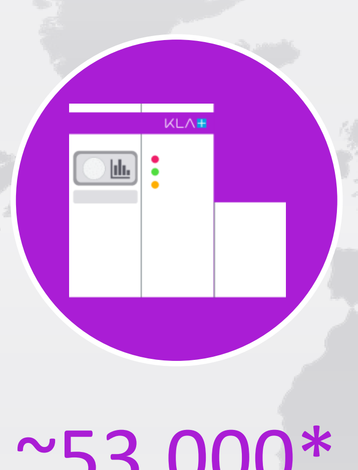
Company Overview

Candela Overview

Power Device Use-Cases

KLA Overview

~10,000*
global employees



~53,000*
tools installed worldwide

$5.2B
CY18 revenue

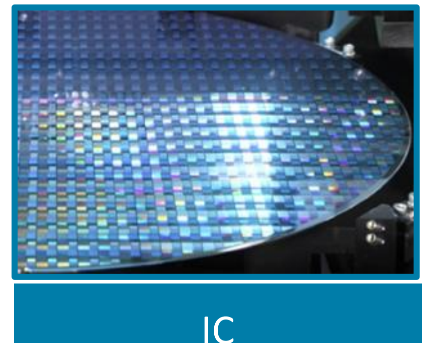
$2.4B
R&D investment over last 4 years

Global Leader in Process Control for 42 Years

*Includes Orbotech and its subsidiaries

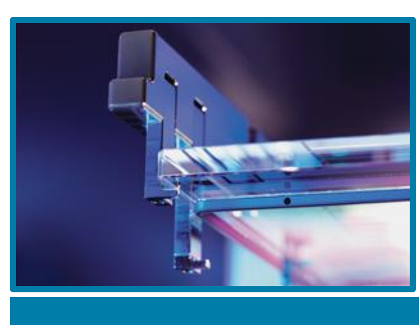
KLA Markets Served

Semiconductor Manufacturing



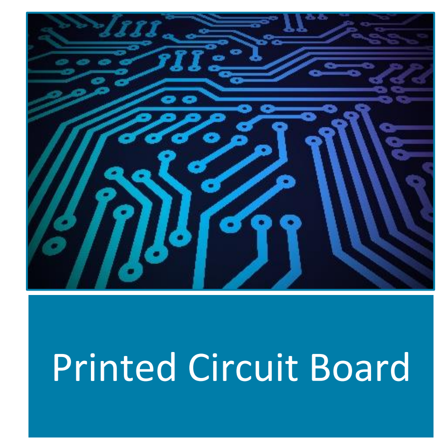
IC Manufacturing

Wafer Manufacturing



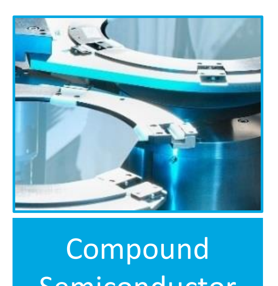
Reticle Manufacturing

IC Packaging



Printed Circuit Board

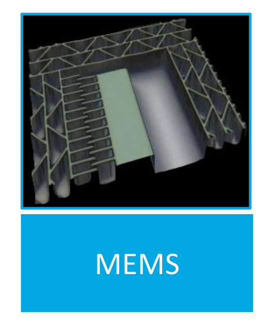
Related Electronics Industries



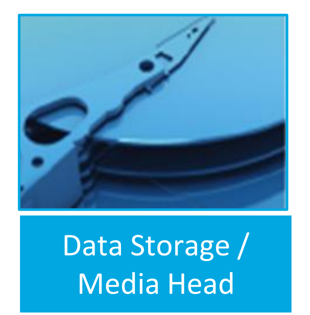
Compound Semiconductor

Power Device

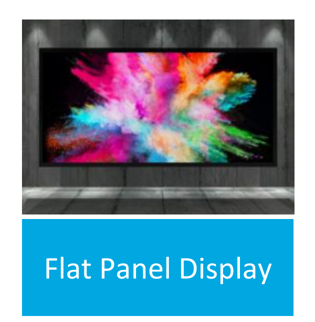
LED



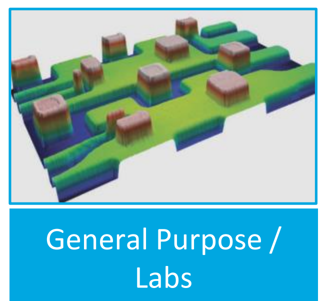
MEMS



Data Storage / Media Head



Flat Panel Display

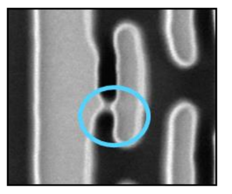
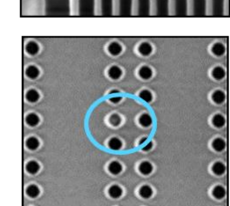
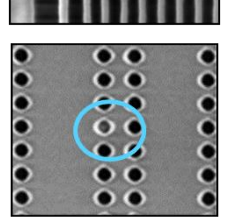
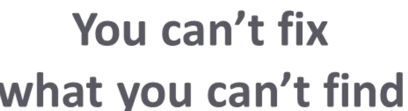
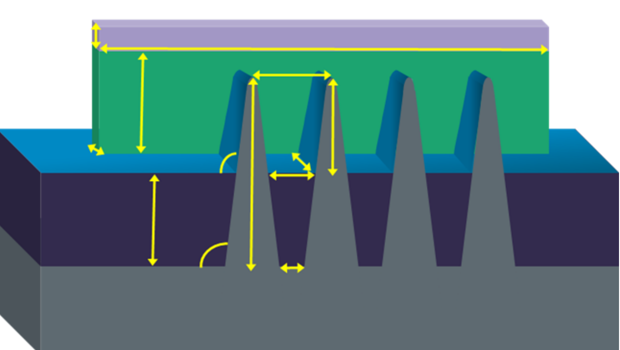


General Purpose / Labs

Focused on Customer Needs

Process Control has two Primary Functions

Inspection	Metrology

You can't fix what you can't find

You can't control what you can't measure

KLA's Mission:

Improve customer yield, performance and time-to-market, enabling the digital age

Strategy:

Provide leading technologies, differentiated solutions and superior customer experiences through collaboration, innovation and execution

Candela Solution

Technology

Multiple techniques that complement each other for **detection** of **increasing library** of **defects** at **throughput** for HVM

Classification

Advanced **multi-channel binning** on a variety of materials based on defect attributes for **user's flexibility**

Tools

Engineering capabilities to perform failure analysis and **drive corrective actions** for process control

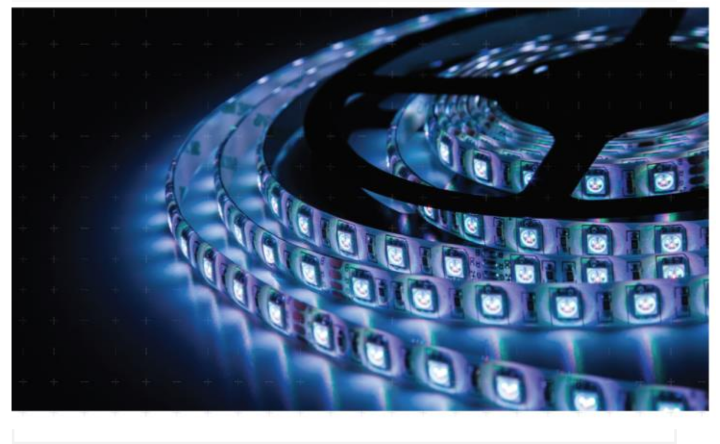
Company Overview

Candela Overview

Power Device Use-Cases

Markets served by Candela

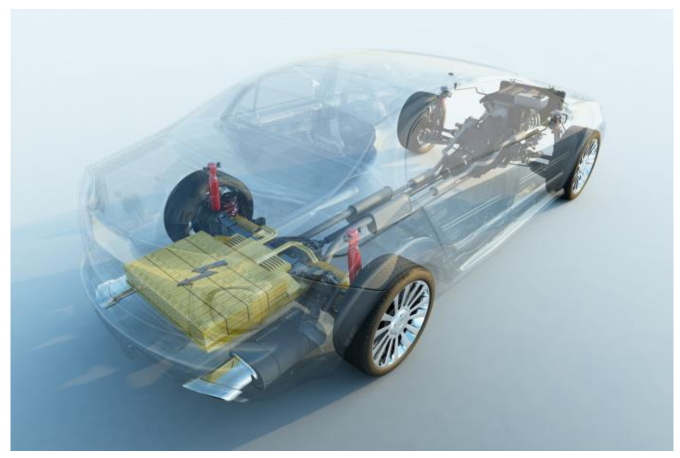
Advanced LED



Communications

IoT

Power Device



PV / Solar

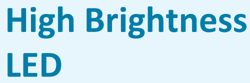
Sensing

KLA

KLA-Tencor's Specialty Device Markets Portfolio

LED, MEMS, Data Storage, Power Devices, Display, AR/VR & Other Compound Semi

High Brightness LED



Zeta-388
PSS Metrology

Candela® 8720
Substrate/Epi Inspection

8920
Wafer Inspection

WI-2280
Dicing Inspection

P-170
Surface Profiling

MEMS

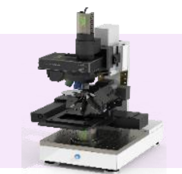
Zeta-388
3D Profiling

8920
Wafer Inspection

P-170
Surface Profiling

Data Storage, Thin Film Head

Candela® 7100



Zeta-20 CM

HRP®-260

Inspection and Metrology

Power Device

Candela® 8520
Sub/Epi Inspection

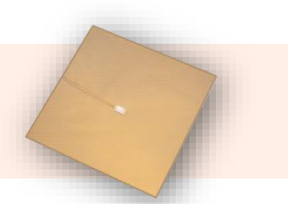
WI-2280
Optical Inspection

8920
Wafer Inspection

P-170
Surface Profiling

Display

ZetaScan Series
Display Inspection



Process Probe™ 2070
In Situ Monitoring

Standards and Reference Cells

KLA-Tencor's Specialty Device Markets Portfolio

LED, MEMS, Data Storage, Power Devices, Display, AR/VR & Other Compound Semi

High Brightness LED

- **Zeta-388** – PSS Metrology
- **Candela® 8720** – Substrate/Epi Inspection
- **8920** – Wafer Inspection
- **WI-2280** – Dicing Inspection
- **P-170** – Surface Profiling

MEMS

- **Zeta-388** – 3D Profiling
- **8920** – Wafer Inspection
- **P-170** – Surface Profiling

Data Storage, Thin Film Head

- **Candela® 7100**
- **Zeta-20 CM**
- **HRP®-260**

Inspection and Metrology

Power Device

- **Candela® 8520** – Sub/Epi Inspection
- **WI-2280** – Optical Inspection
- **8920** – Wafer Inspection
- **P-170** – Surface Profiling

Display

- **ZetaScan Series** – Display Inspection
- **Process Probe™ 2070** – In Situ Monitoring

Standards and Reference Cells

Candela Product Evolution

2002

Wafer Inspection started with CS1/CS2

2004

Kick-off R&D and Production applications in LED/Compound Semi and QC control at suppliers with CS10/CS20

KLA-Tencor acquires Candela

2007

Edge Inspection for semiconductors. Successful transition to SWIFT

2010

Production ramp for LED and supply chain management with 8620

2013

Introduction of industry's 1st integrated surface + PL inspection solution for PD Market with CS920

Advanced LED Market Capacity buys with 8720

2017

Production ramp for Compound Semi and TM/TQ/PQ with 8420

KLA-Tencor acquires ZETA

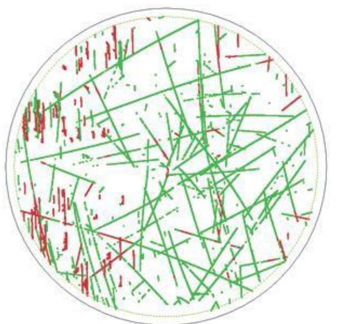
2019

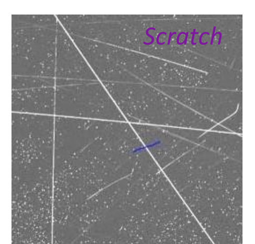
Rebranding: We are now KLA

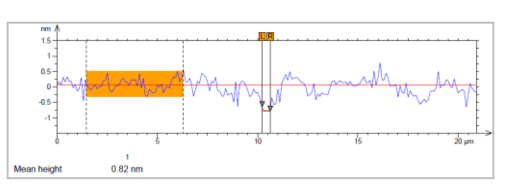
Improved Integrated surface + PL inspection solution for PD Market with **8520**

Candela 8520 Integrated Surface + PL Inspection Solution for Power Device Applications

High sensitivity to CMP scratches on SiC substrates

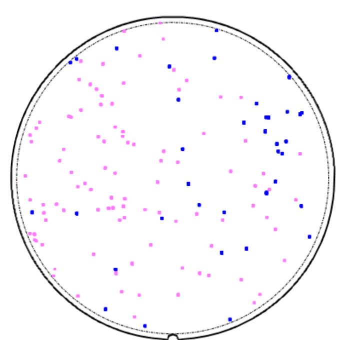


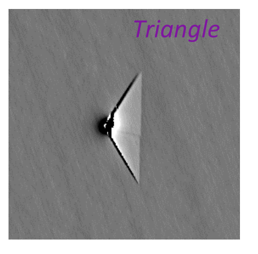


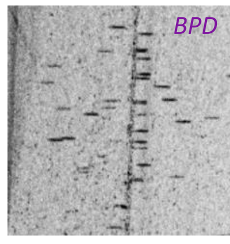


Length = 20.90 µm Pt = 1.57 nm Scale = 3.00 nm

Integrated Surface + Photoluminescence for detection of SiC Epitaxy defects







SiC Substrate Defects of Interest

- Scratches that may results in Yield Impacting Epitaxial Defects
- Stain that may impact Epitaxy Quality
- Fast and accurate non-destructive differentiation of Micropipes & Surface Pits
- **Improved sensitivity** for crystal defects over previous generation

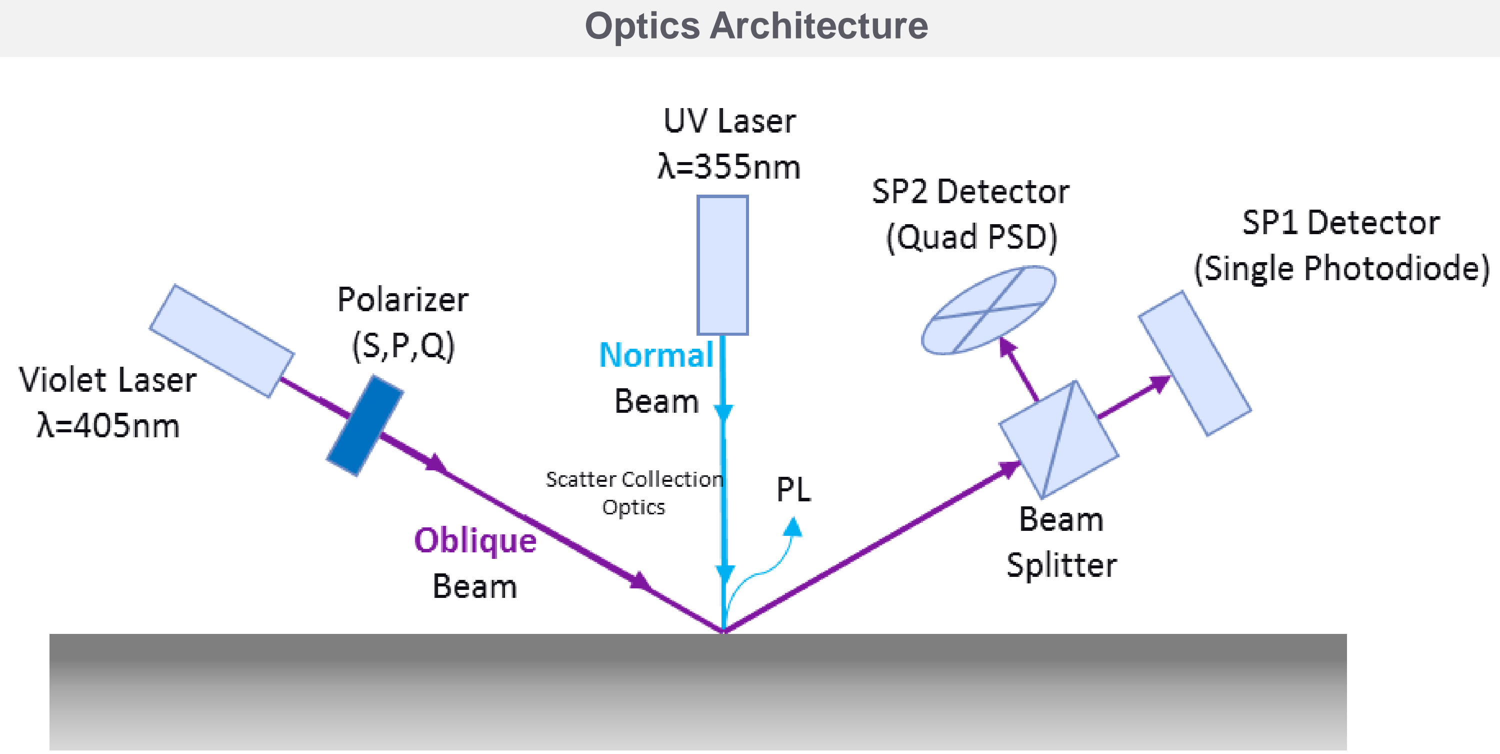
SiC Epitaxy Defects of Interest

- Killer Surface/PL defects: Triangles, Carrots, Pits, Step Bunching & BPDs
- R&D → production coverage
- **Improved sensitivity** over previous generation

R&D and production ready

- 2" – 8" automation
- No mandatory scan edge exclusion
- ≤ 100nm PSL equivalent sensitivity on Si and SiC
- In-situ image review of scanned data
- Wafer grading based on PASS/FAIL criteria
- **Improved throughput** over previous generation
- Monitor defects by count, density and other metrics
- GEM-SECS / KLARF compatible

Candela 8520 : System Overview

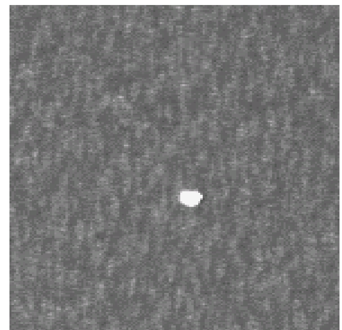


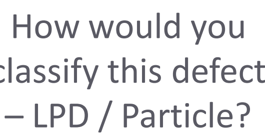
- **2 incident lasers** (Normal/UV & Oblique/Violet)
- **9 Detectors**
  - Brightfield Channels
    - *Reflectivity* (~BF microscope)
    - *Slope* (~topography)
    - *Phase* (~ellipsometer)
  - Darkfield Channels
    - *Scatter* (normal & oblique)
    - *Photoluminescence* (optimized for SiC)

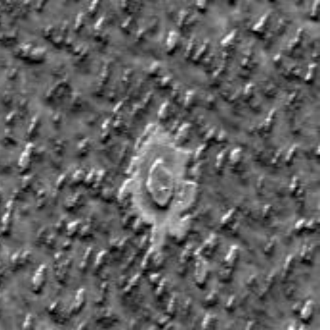
Identification of Killer Defects is Critical

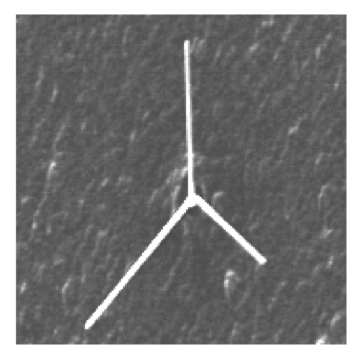
Simultaneous collection of variety of information on the **Candela** allows user to **accurately classify process defects** from non-killers

Scatter Oblique | Topography | Scatter Normal









How would you classify this defect – LPD / Particle?

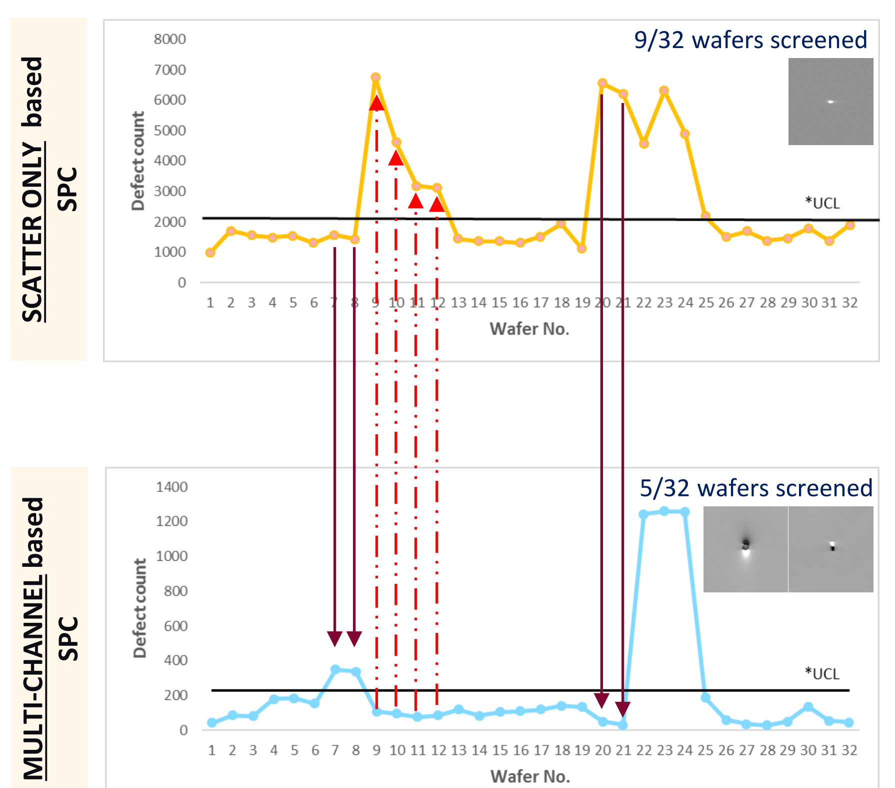
Slope channel is **sensitive** to **morphological variations** → epi disturbance visible

Scatter Normal channel is **sensitive** to **cracks** → originating from epi defect

Enabling users to make informed decisions

Feedback for corrective actions

Accurate classification helps screen appropriate wafers for failure analysis



4 wafers containing killer process-related defects **missed screening** criteria, based on scatter-only response

4 wafers containing non-killer defects **oversampled** for **screening** criteria, based on scatter-only response

Screening based on process killers helps drive relevant corrective actions. Particulates can be removed through cleaning process

Candela 8520 : System Overview

Optics Architecture

UV Laser
λ=355nm
SP2 Detector
(Quad PSD)
SP1 Detector
(Single Photodiode)
Polarizer
(S,P,Q)
Violet Laser
λ=405nm
Normal
Beam
Scatter Collection
Optics
PL
Oblique
Beam
Beam
Splitter

Quad cell photo detector sensitive to surface SLOPE variations

Nominal beam position
Deflected beam position 1
Deflected beam position 2
Zr signal
Zr signal
Zc signal
Zc signal
+ slope
- slope
detector
surface
(A)
(B)
(C)
(D)

- **Topography signature on Candela for defects >20µm, correlates well with defect morphology measured on a profiler.**
- **Channel used for detection and classification of macro pit/bumps**

Example

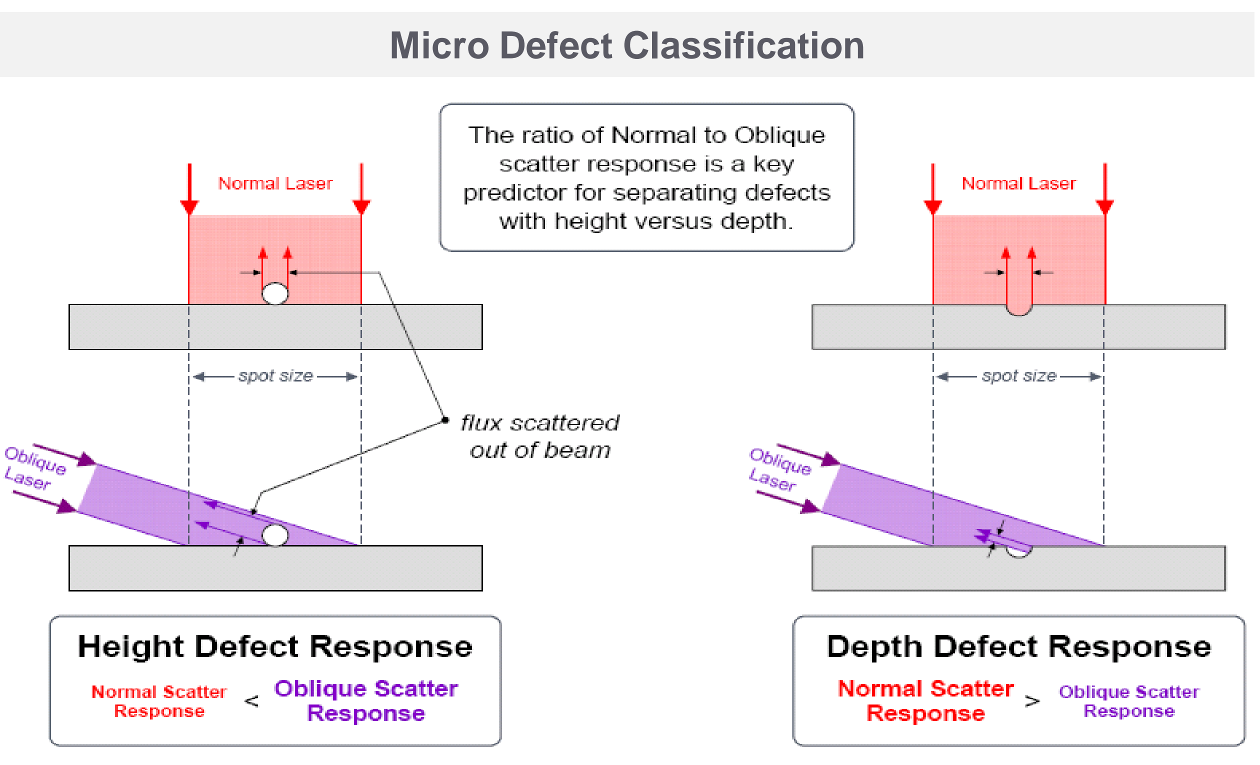
Can be viewed from 2 angles

Viewing Angle
Defect Cross-section (Slope Variation)
Circumferential Topography
Radial Topography

Width: ~ 85 µm
Bump Signature on Candela
Pit Signature on Candela
Pit Signature on Candela
nm
200
0
-200
-400
-600
0
10
20
30
40
50
60
70
80
90
100
110
120
130

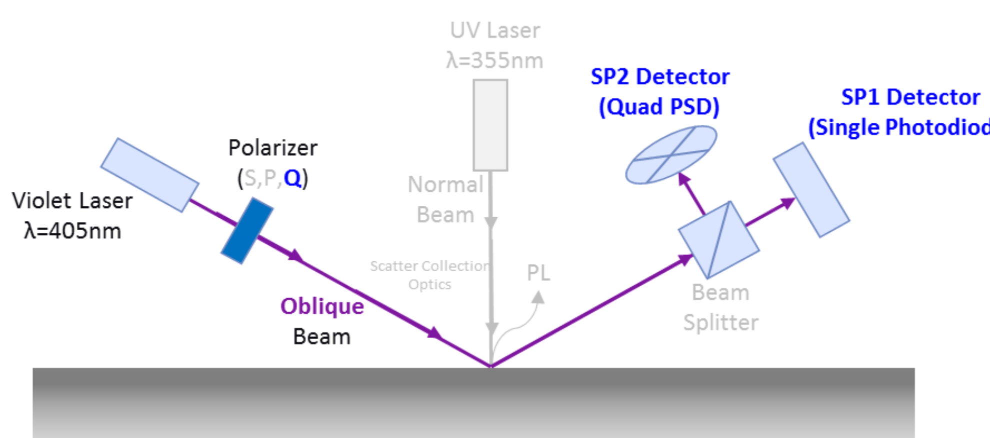
Candela 8520 : System Overview

- For defects <20µm, **ratio** of optical responses from **Normal** and **Oblique** scatter is used to **distinguish Pits** from **Particles**
- For Pits, Normal > Oblique
- For Particles, Oblique > Normal



Candela 8520 : System Overview

Optics Architecture



- **2 incident lasers** (Normal/UV & Oblique/Violet)
- **9 Detectors**
  - Brightfield Channels
    - *Reflectivity* (~BF microscope)
    - *Slope* (~topography)
    - *Phase* (~ellipsometer)
  - Darkfield Channels
    - *Scatter* (normal & oblique)
    - *Photoluminescence* (optimized for SiC)

Theory of operation

Q Pol.
S Pol.
P Pol.
Stain
Wafer

Input Polarization: Q

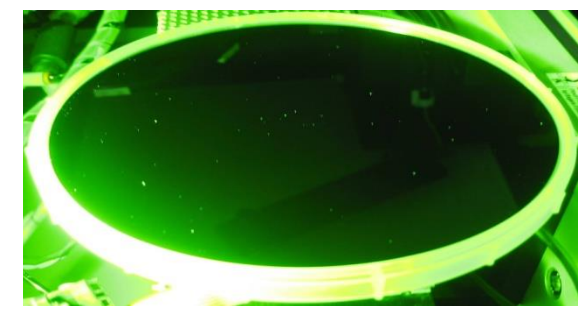
Pq
Sq
Phase

Pq and Sq are the individual components of the reflected light from the stain

Path difference between top & bottom surface of stain → phase difference in reflected beams

Example of Phase Imaging for Stain detection

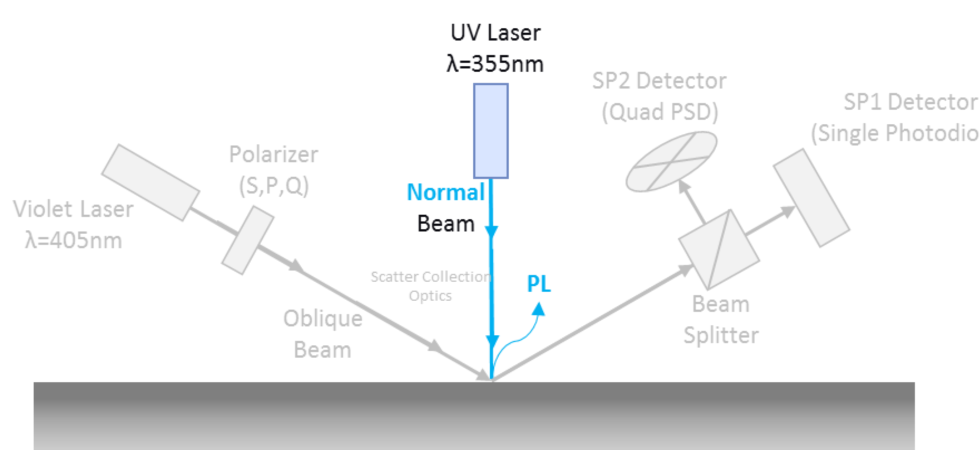
Candela Phase image of Silicon substrate



Bright light inspection image of Silicon substrate

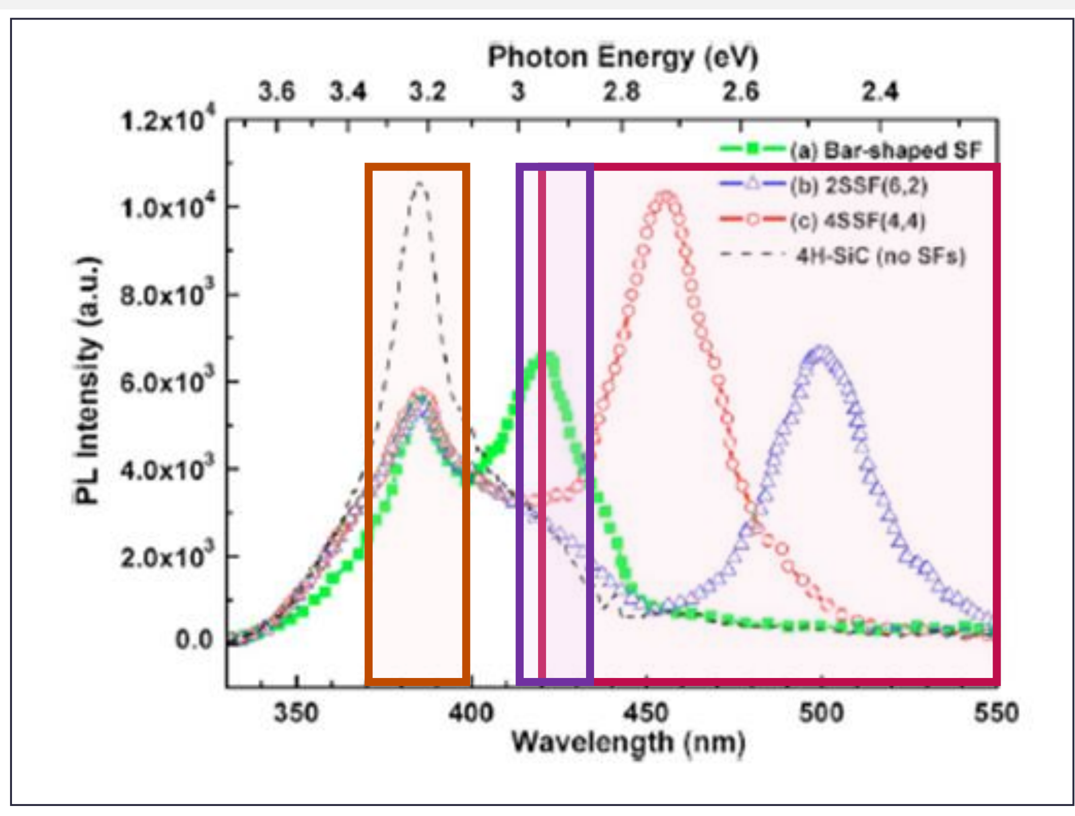
Candela 8520 : Technology Overview

Optics Architecture



- **2 incident lasers** (Normal/UV & Oblique/Violet)
- **7 Detectors**
  - Brightfield Channels
    - *Reflectivity* (~BF microscope)
    - *Slope* (~topography)
    - *Phase* (~ellipsometer)
  - Darkfield Channels
    - *Scatter* (normal & oblique)
    - *Photoluminescence* (optimized for SiC)

PL channel is optimized to detect crystal defects on SiC Substrate and Epi



PL collection range: 370nm – 700nm

Candela 8520 : Technology Overview

Data Acquisition

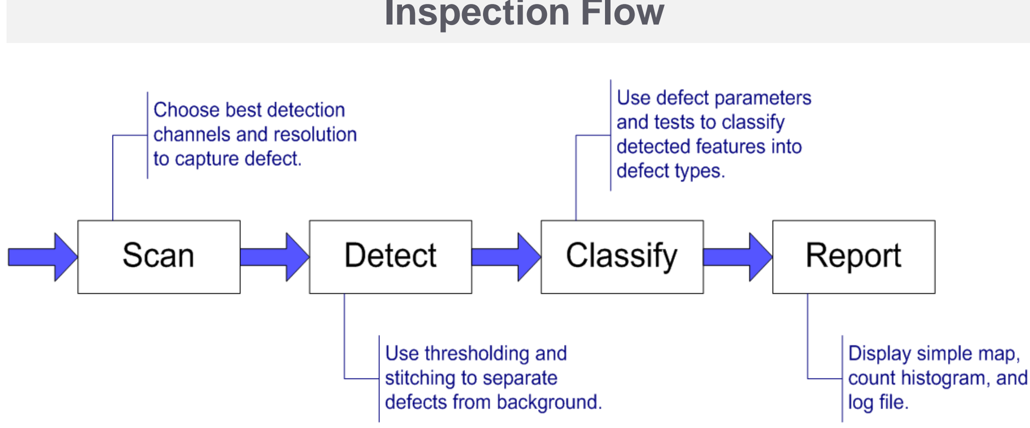
Sample is scanned from edge to center in a spiral path

Angular Resolution

Radial resolution

- Wafer spins counter clockwise
- Max speed = 5000 RPM
- Optics head moves from edge to center (no scan edge exclusion required)
- Step size → radial resolution
- Track sampling frequency → angular resolution
- Scan resolution = F_n (radial res, angular res)

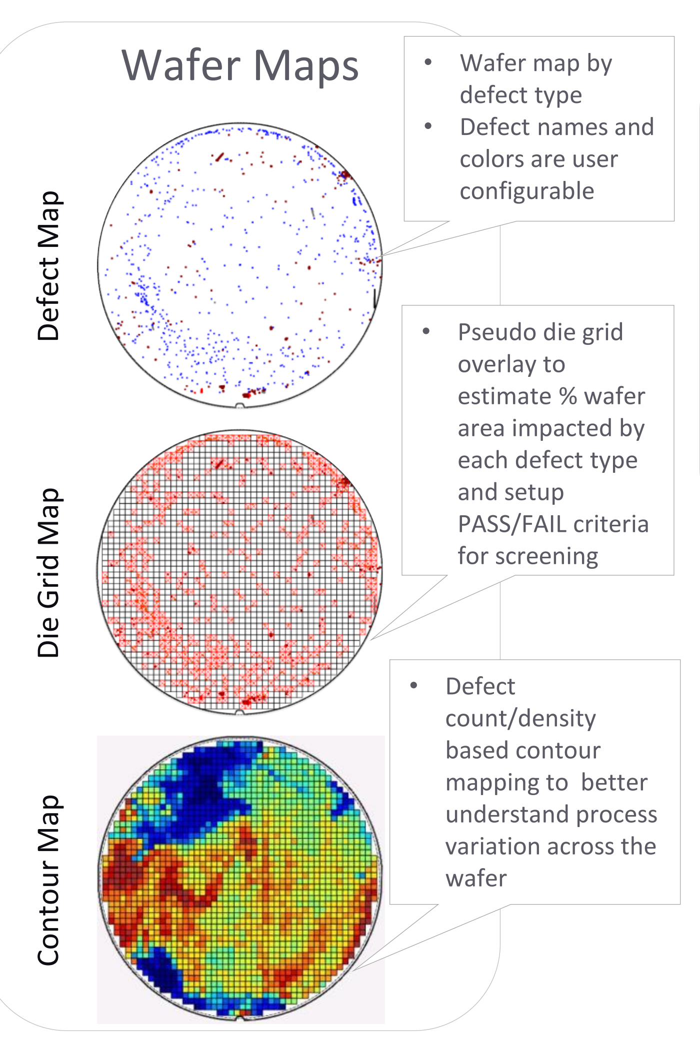
Inspection Flow



- 8520 recipe is user configurable to meet inspection requirements
- Classification recipe can be created on-tool or on offline PC using raw data
- Many output options available

Candela 8520 Inspection Output provides a lot of valuable information for Power Device Industry

Wafer Maps

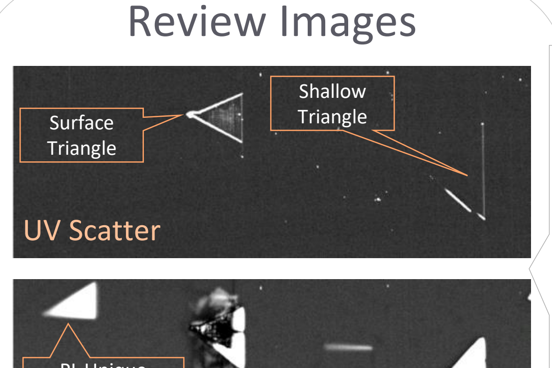


- Wafer map by defect type
- Defect names and colors are user configurable

- Pseudo die grid overlay to estimate % wafer area impacted by each defect type and setup PASS/FAIL criteria for screening

- Defect count/density based contour mapping to better understand process variation across the wafer

Review Images



- One click image review across multiple channels simultaneously to better understand defect characteristics

Defect Pareto

Count

	DOI 1	DOI 2	DOI 3	DOI 4	DOI 5	DOI 6	DOI 7	DOI 8
Count	13	51	19	3	2	4	28	23

Results Summary

Statistics by defect type

Defect Summary

Defect Name	Count	Density (per sq mm)
DOI 1	8	0.00104
DOI 2	2377	0.30935
DOI 3	153	0.01991
DOI 4	1	0.00013
DOI 5	785	0.10216
DOI 6	1	0.00013
DOI 7	161	0.02095
Total Defects	3486	0.45368

Defect Length

Sizing by Length

Defect Name	Max Length (um)	Min Length (um)	Mean Length (um)	Total Length (um)	MaxDR (um)
DOI 8	1296.98790	5.00992	568.67514	1706.02542	556.00000

Wafer Grading

Die Summary

Total Number of Dies		276	
Defect Type	Number of Failed Dies	% Wafer Impact	Status
DOI 1	32	11.59420%	FAIL
DOI 2	48	17.39130%	FAIL
DOI 3	51	18.47826%	FAIL
DOI 4	1	0.36232%	PASS
DOI 5	195	70.65217%	FAIL
DOI 6	6	2.17391%	PASS
Total	223	80.79710%	FAIL

Offline Defect Review Helps Maximize Inspection Tool Uptime and Production Utilization

INSPECTION & REVIEW

HVM INSPECTION & SPC

OOC offline review

UTILIZATION
10 wph
50% INSPECTION
50% REVIEW

UTILIZATION
15 wph
75% INSPECTION
25% REVIEW

1-2 reviews/hr
15min production downtime

UTILIZATION
20 wph
100% INSPECTION
OFFLINE REVIEW

pilot production

INSPECTION & REVIEW

HVM

INSPECTION & SPC (offline review)

Width: ~ 27µm
Depth: ~ 0.83µm

MXAM offline review

Offline Review Options

Zeta-20

multiple review objectives

1. optical microscope
2. Zeta-20 optical profiler
   - 2D image
   - 3D image
   - 3D with depth color coding
   - Metrology data
3. AFM
   - 3nm resolution

OM image

surface triangle

2D image

surface triangle

3D image

surface triangle

AFM objective

threading dislocation

3D with depth color coding

Width : ~ 2μm

Depth : ~ 5nm depth

Candela 8520 : Summary of improvements over CS920

Retain capabilities of Candela CS920

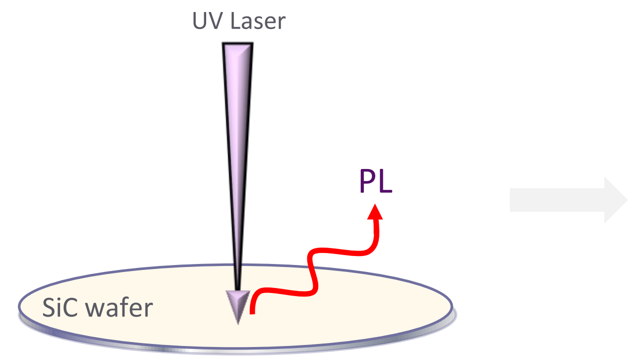
- ✓ Multi-channel detection and classification
- ✓ Versatility (capable of inspecting multiple material systems)
- ✓ GEM-SECS/KLARF compatibility
- ✓ High inspection report output quality
- ✓ On-tool review for DSA
- ✓ Engineering tools to predict wafer yield

Performance Enhancements Implemented

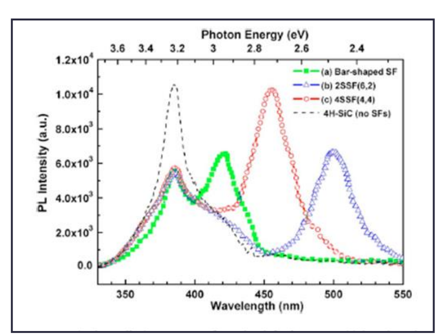
- Improved detection on crystal defects
- New algorithm for improved defect detection
- Higher Throughput
- Additional engineering tools to aid with better process control
- Improvement in wafer handling

Candela 8520 : Improvements over CS920 (1)

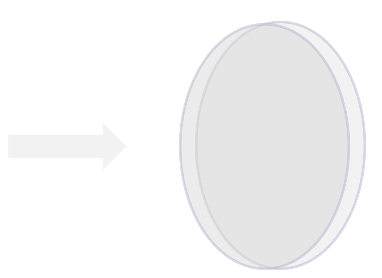
Crystal Defect Detection on SiC substrates



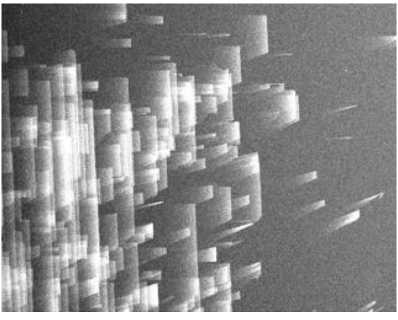
SiC PL excited by UV Laser



PL Spectrum from SiC sample collected

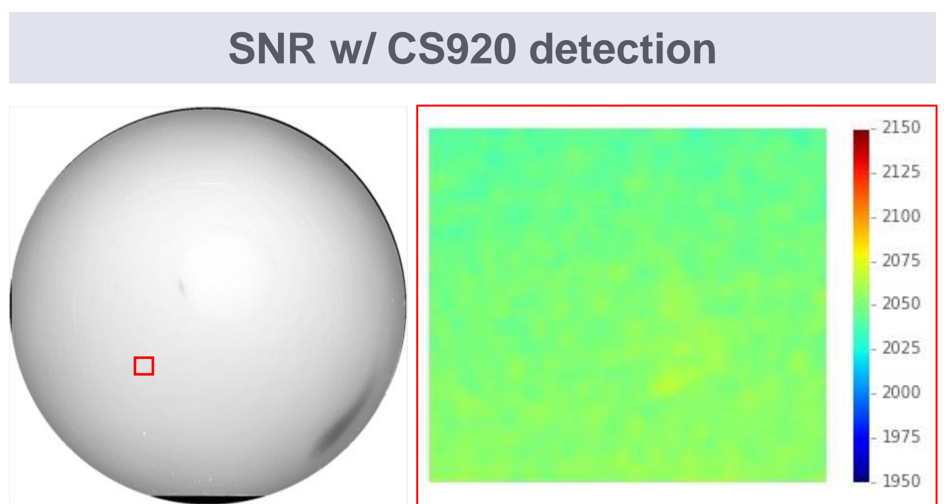


Collection optimized for PL on SiC substrate

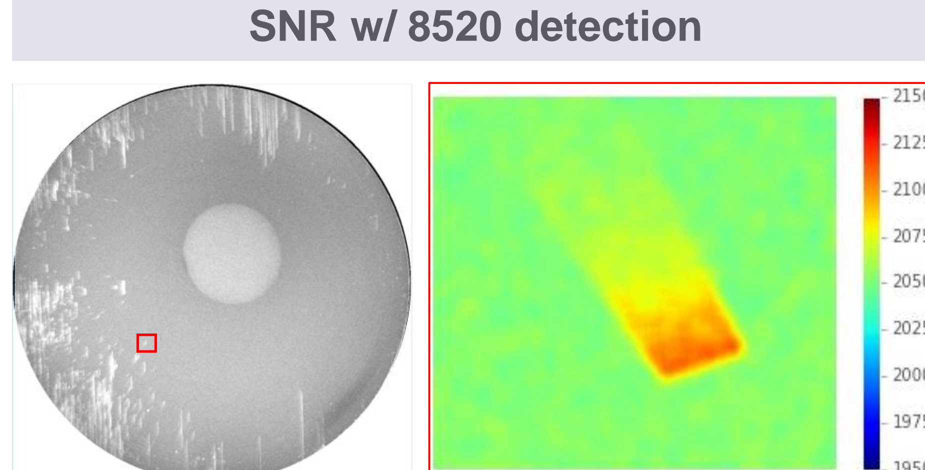


Stacking Faults detected

SNR w/ CS920 detection



SNR w/ 8520 detection

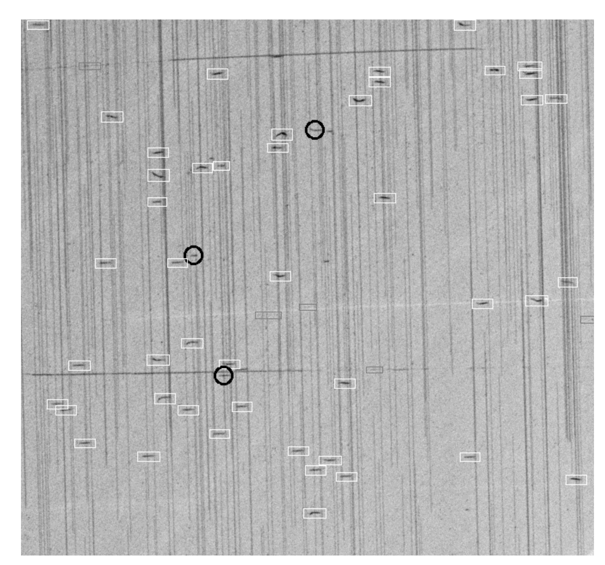


Candela 8520 : Improvements over CS920 (2)

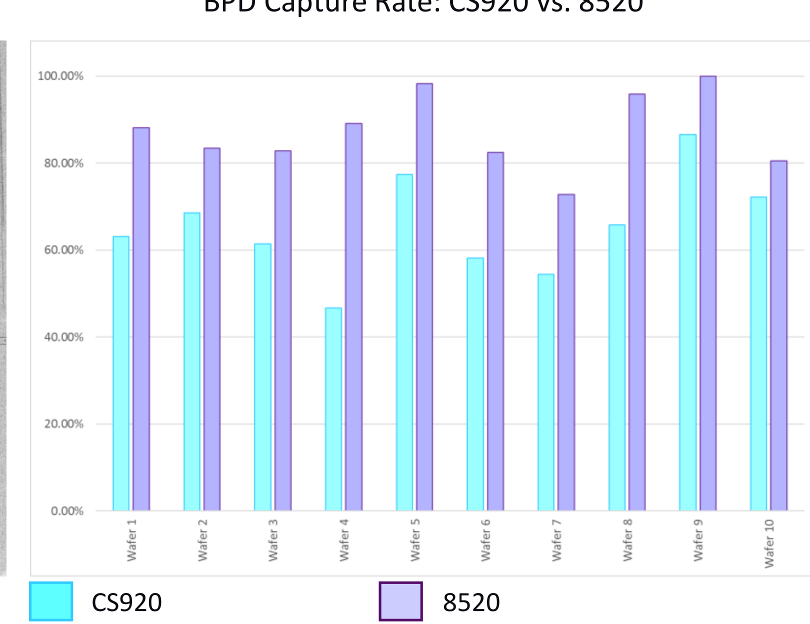
Enhanced BPD Detection on SiC Epi

BPD Algo	CS920	8520
Detection approach	Mercator view	X-Y plane
Detection flow	Same algo for all defects	Special multi-step advanced algorithm for BPD only
Capture Rate	X	Up to 2X
Purity	Similar performance	
Throughput Impact	None	

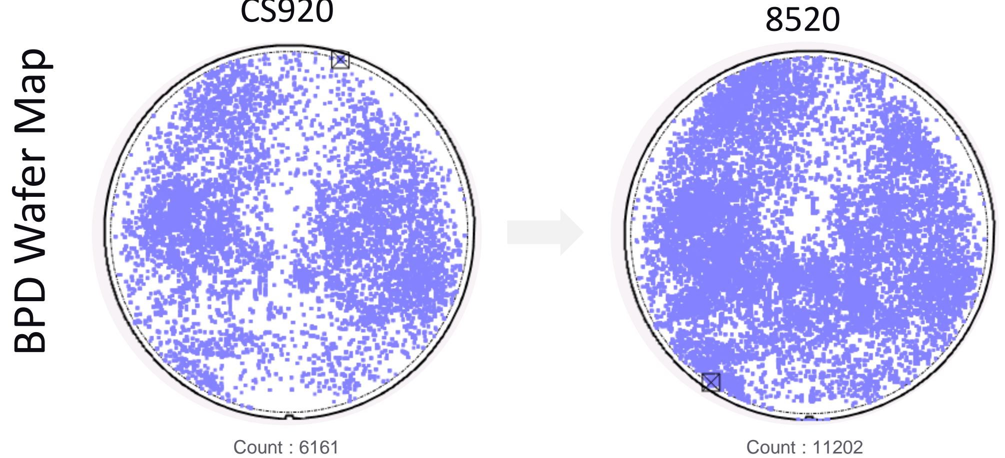
Detection in XY plane



BPD Capture Rate: CS920 vs. 8520



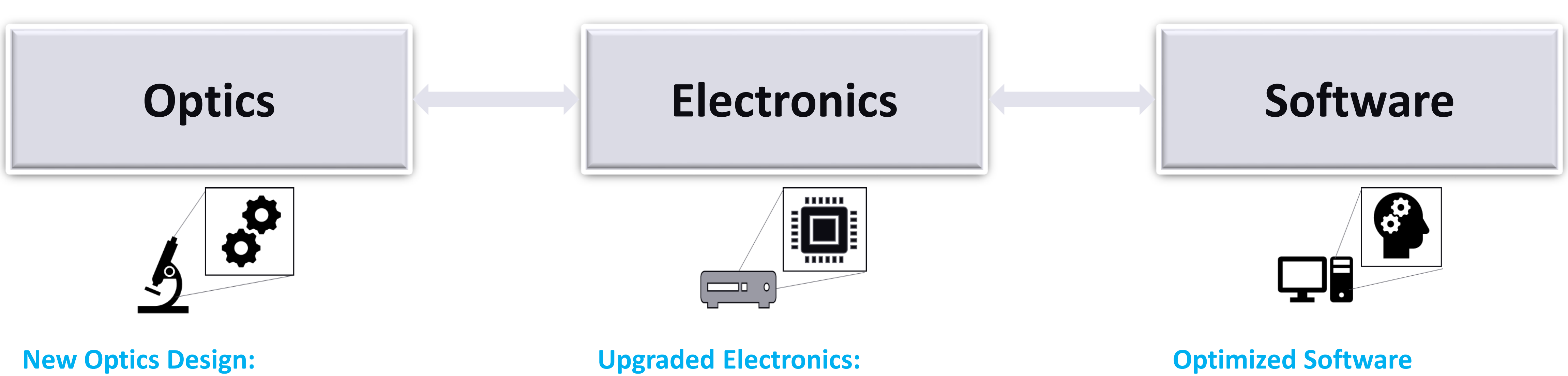
CS920 8520



Up to 2X increment in BPD defect count at similar classification purity w/ no impact to throughput

Candela 8520 : Improvements over CS920 (3)

Throughput Enhancements



New Optics Design:

Optimized for faster simultaneous detection of all defect types on both SiC substrate and SiC Epitaxy wafers

Upgraded Electronics:

Scan up to 8 channels scan in 1 pass (from previous of 4 in 1 pass)

Optimized Software Architecture:

For reduced overhead, better data management and faster backend processing

Up to 2.5x throughput improvement for **production** inspection **use-cases**

Candela 8520 : Improvements over CS920 (3)

Throughput for production test use-cases

SiC Substrate

Resolution	Wafer Size	Surface Def	Surface Def + MP	Surface Def + MP + SF*
CS920				
Production Mode	4"	24 (1)	16 (2)	N.A.
	6"	18 (1)	11 (2)	N.A.
R&D Mode	4"	13 (1)	8 (2)	N.A.
	6"	9 (1)	5 (2)	N.A.
8520				
Production Mode	4"	28 (1)	18 (2)	12 (2)
	6"	22 (1)	13 (2)	8 (2)
R&D Mode	4"	16 (1)	9 (2)	6 (2)
	6"	12 (1)	6 (2)	4 (2)

Note: Image save ON, SF → Stacking Fault, MP → Micropipe, (x) = # scan pass

* Preliminary Results

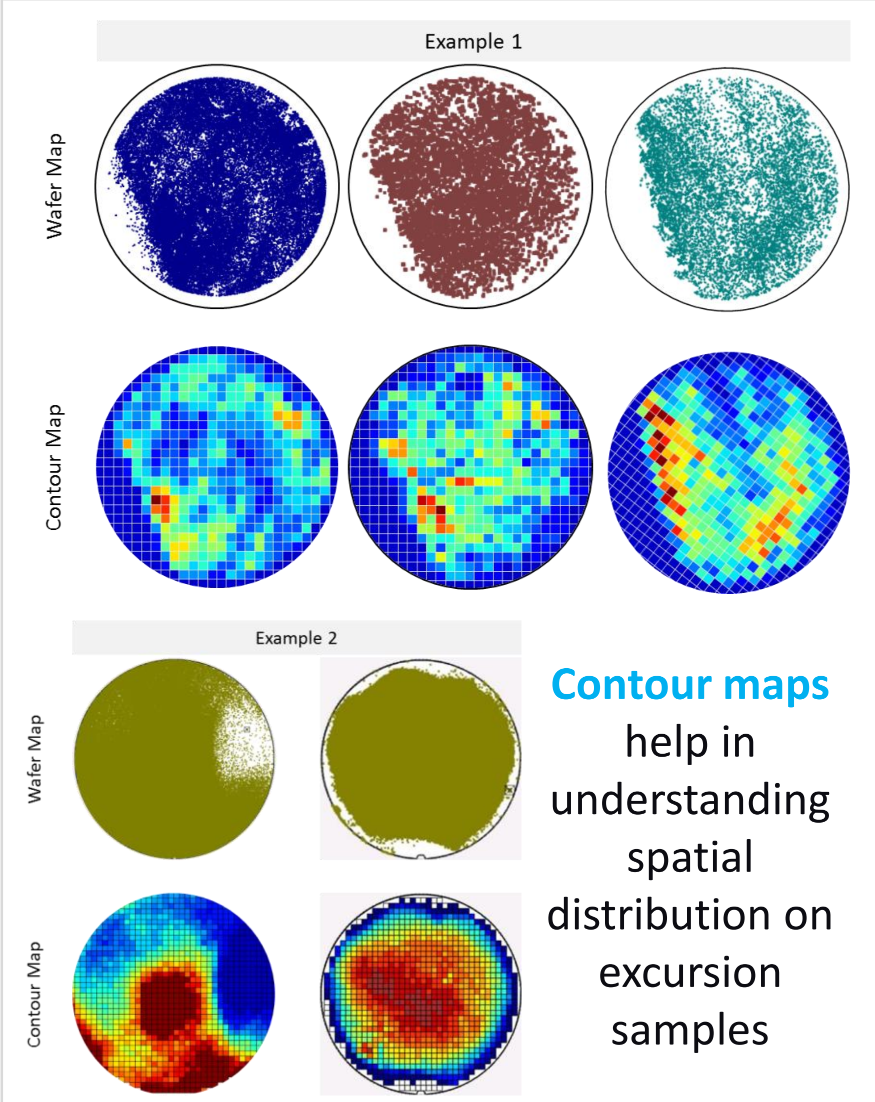
Throughput Improvement: Up to 30% for existing cases + added Capability for Stacking Fault Detection

SiC Epi

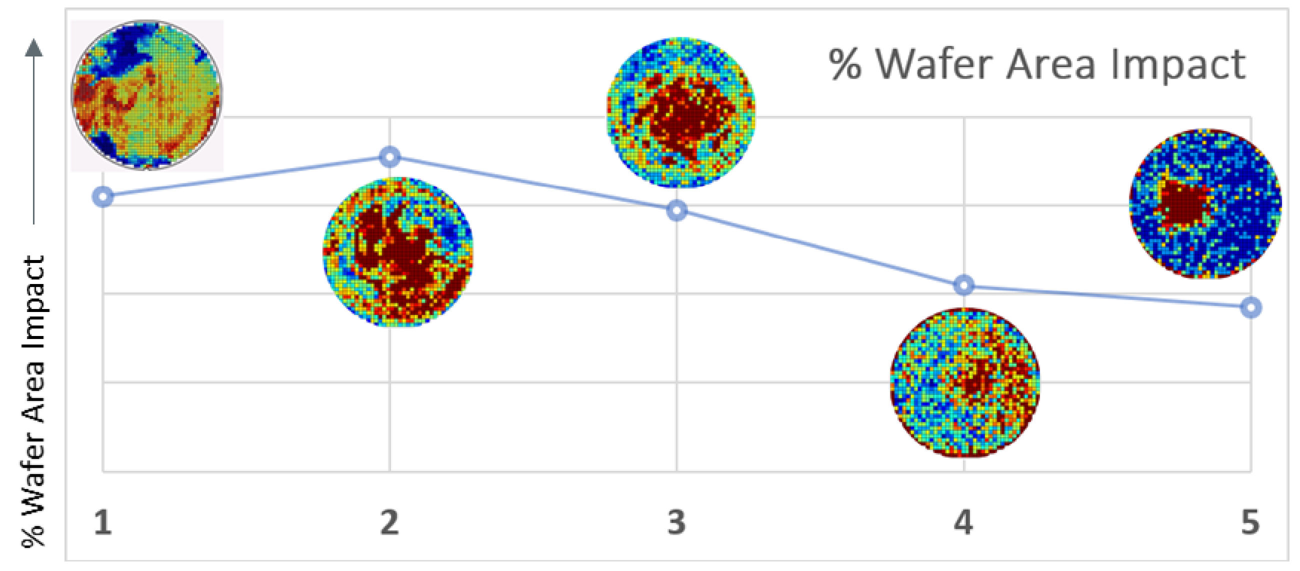
Resolution	Wafer Size	Surface Def + Macro PL	Surface Def + Macro PL + BPD
CS920 (2 pass scan)			
Production Mode	4"	8 (2)	8 (2)
	6"	6 (2)	6 (2)
R&D Mode	4"	4 (2)	4 (2)
	6"	3 (2)	3 (2)
8520 (1 pass scan)			
Production Mode	4"	20 (1)	20 (1)
	6"	15 (1)	15 (1)
R&D Mode	4"	10 (1)	10 (1)
	6"	7 (1)	7 (1)

Throughput Improvement: Up to 2.5 X

Engineering tools to aid with better process control



Contour maps help in understanding spatial distribution on excursion samples



- Wafers with similar % wafer area impact may have different spatial distributions
- Spatial distributions may provide additional information for tuning process parameters

Candela 8520 : Improvements over CS920 (4)

Auto wafer recovery in case of low vacuum

S. No.	Failure Condition	Action	Pre software version 10.4	Software version 10.4
1	Load from cassette to end effector	Wafer is returned to cassette and does not require recovery process	✓	✓
2	Load from end effector to pre-aligner	Retry, if fail return wafer to cassette. Proceed to next wafer	✗	✓
3	Load from pre-aligner to end effector	Retry, if fail wafer will require manual recovery.	✗	✓
4	Load from end effector to transfer station	Retry, if fail return wafer to cassette. Proceed to next wafer	✗	✓
5	Load from transfer station to chuck	1)If vacuum on transfer station, robot will move wafer back to cassette 2)If no vacuum on transfer station, wafer will require manual recovery	✓	✓
6	Load from chuck to transfer station	1)If chuck vacuum is above a pre-defined threshold, robot will move wafer back to cassette 2)If chuck vacuum is below this pre-defined threshold, wafer will require manual recovery	✗	✓

Candela 8520 : Improvement Comparison

Item	Description	CS920	8520
Substrate Stacking Fault	Able to capture Stacking Faults on SiC substrate	<50% capture	>80% capture rate
BPD only detection	BPD on thin SiC Epi layers are captured at High Purity	1x	Up to 2x more counts
Throughput – SiC Substrate	Improved optics + Improved processing	1x	Up to 1.3X faster
Throughput – SiC Epi	Improved optics + Improved processing + 1 pass scan for surface + PL channels	1x	Up to 2.5X faster
SW Feature – Defect density Map	Able to show density for high excursion defect to understand spatial distribution	None	Yes
SW Feature – Improved Auto wafer Recovery	Less manual intervention for wafer recovery	Limited	Automatic wafer recovery for most cases with minimal manual intervention

Company Overview

Candela Overview

Power Device Use-Cases

SiC Process Inspection Points

SiC Boule → Wafer Cutting → Patterning → Power Device

Inspection Points

Xtal Growth → Slicing → Lapping → Polishing → Cleaning → Epitaxy → Wafer Fabrication → Thinning & Dicing → Test & Sorting → Packaging / Ship

Substrate Quality Control
- SiC Material Defects
- Substrate Vendor Comparison
- IQC on Substrates

Epi Growth Process Control
- Epi defect inspection
- Substrate to Epi correlation
- Micropit detection
- MOCVD SPC Charts
- MOCVD Vendor Comparison

In-Line Production Monitoring
- Reflective Layer Monitoring
- Tool Qualification
- Process Monitor

SiC Process Inspection Points

SiC Boule → Wafer Cutting → Patterning → Power Device

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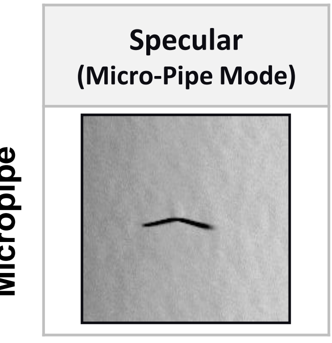
Substrate Quality Control
- **SiC Material Defects**
- **Substrate Vendor Comparison**
- **IQC on Substrates**

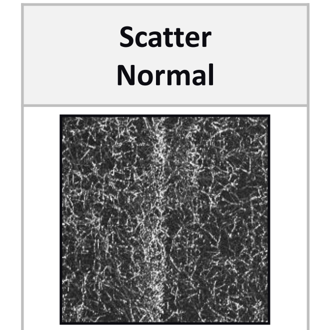
Epi Growth Process Control
- Epi defect inspection
- Substrate to Epi correlation
- Micropit detection
- MOCVD SPC Charts
- MOCVD Vendor Comparison

In-Line Production Monitoring
- Reflective Layer Monitoring
- Tool Qualification
- Process Monitor

SiC Material Defects

Defect Type	Scatter Normal	Scatter Oblique	Vis-PL	Topo-graphy	Phase
Scratch					
Stacking Fault					
Micropit (N > O)					
Particle (O > N)					
Grain Boundary					

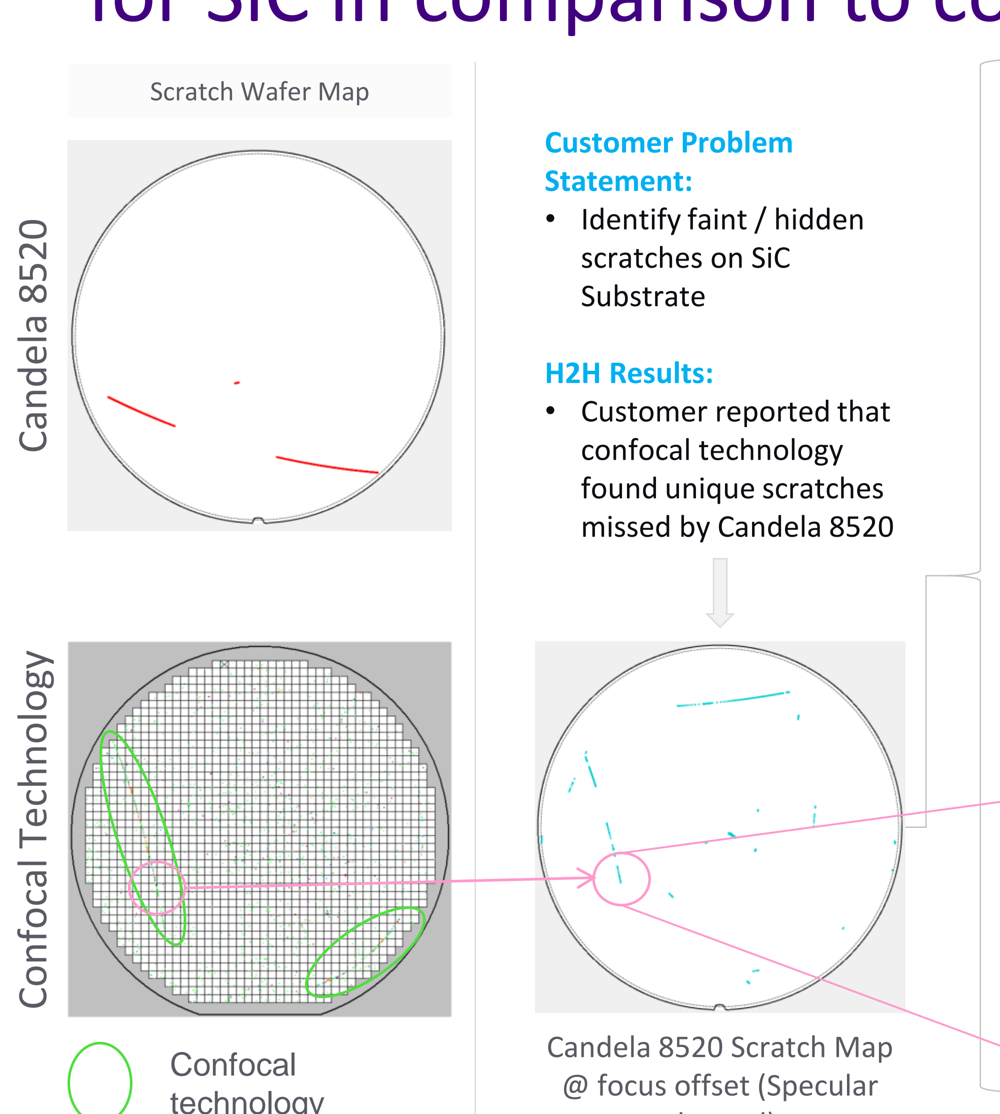




- **Multiple channels available on Candela 8520**
- **Defect signatures are unique to certain channels**
- **Simple rules are applied for accurate classification**

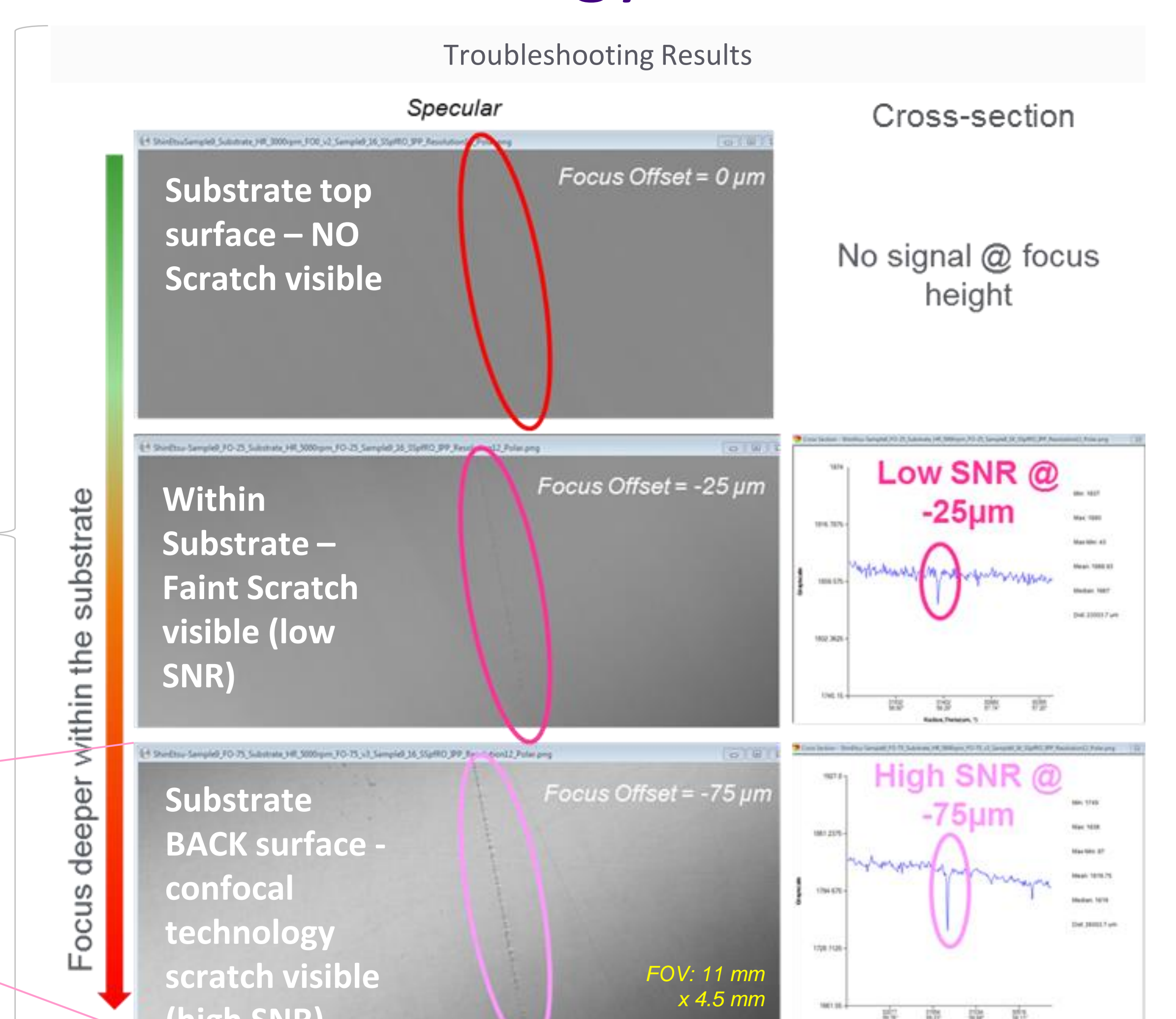
KLA

UV laser incidence on Candela 8520 has **better FS/BS separation** for SiC in comparison to confocal technology



Customer Problem Statement:
- Identify faint / hidden scratches on SiC Substrate

H2H Results:
- Customer reported that confocal technology found unique scratches missed by Candela 8520



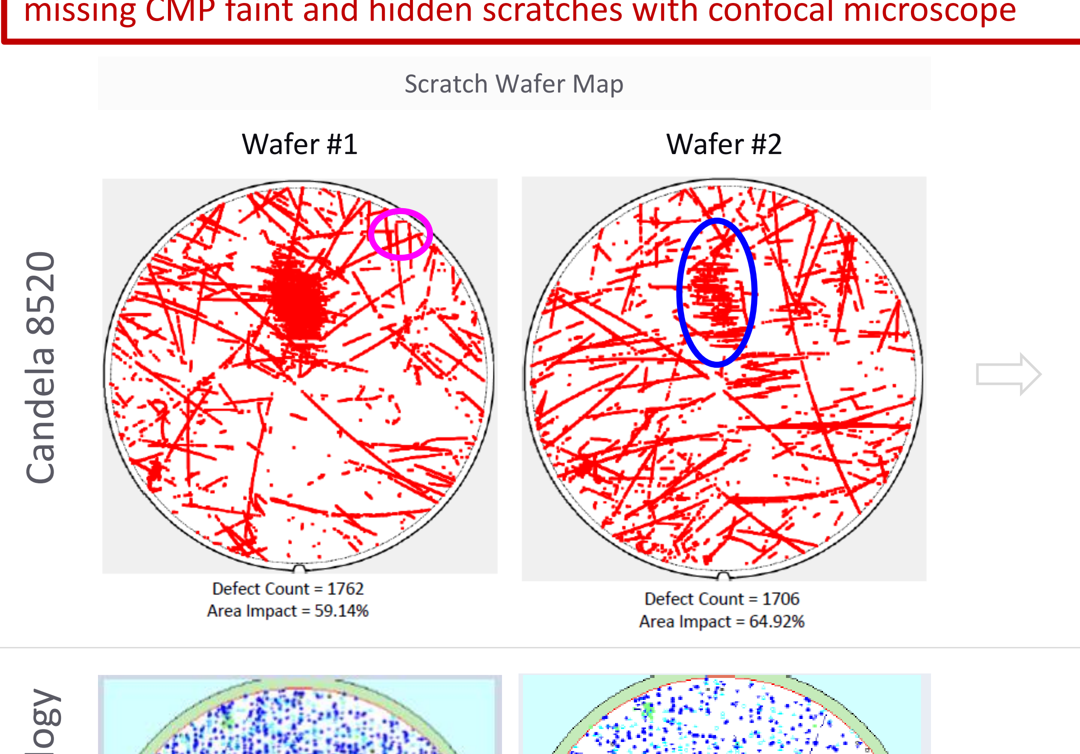
Conclusion

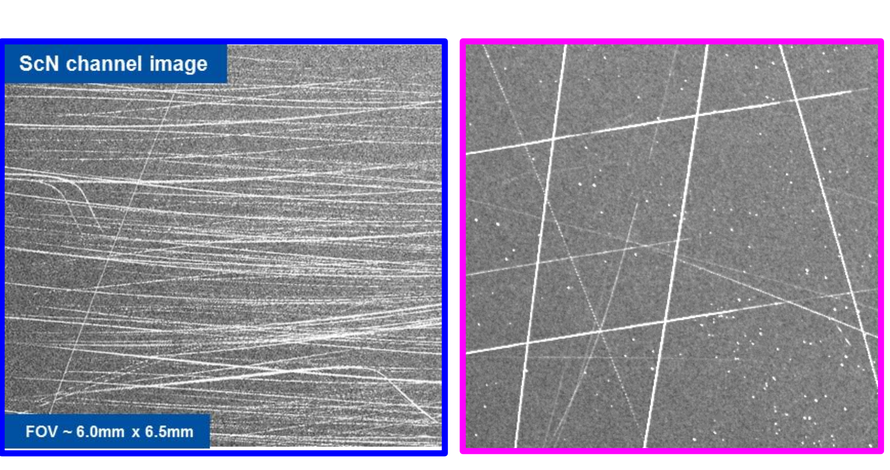
- **Primary channel** for scratch detection on Candela 8520 is **Scatter Normal**
- Skin depth of Normal laser is ~50µm
- Good FS/BS separation achieved with Scatter Normal channel
- **Scratch** found on **confocal technology** was **detected** with focal plane was set to **wafer's back side**
- **Candela 8520** has **better FS/BS** separation in comparison to confocal technology **on** transparent samples like **SiC**

Head-to-Head comparison

Customer Problem Statement:
missing CMP faint and hidden scratches with confocal microscope

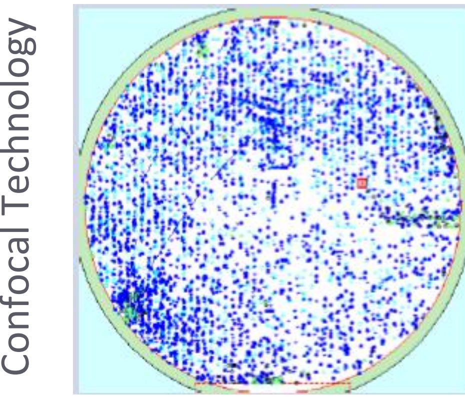
Scratch Wafer Map | Scratch Image

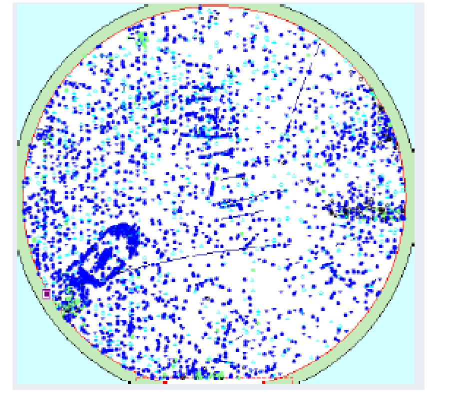


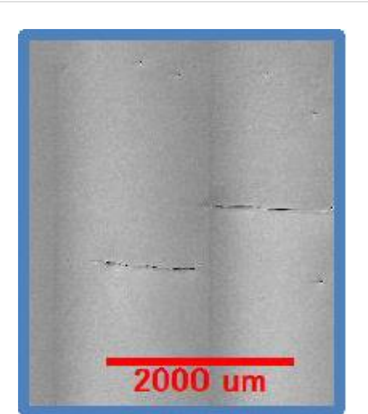


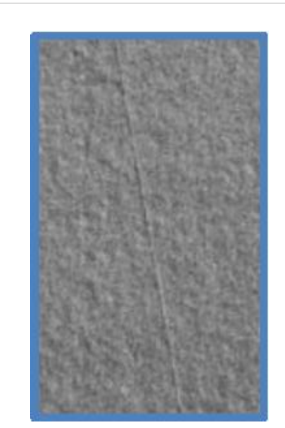
Many faint (SNR >2) CMP related scratches identified → Wafer area impact >50%

Confocal Technology









Typical scratch example images

- Scratches are barely visible on confocal OM images (extremely low SNR)
- Step bunching along with vacuum wand mark from backside detected and reported as surface defects

Substrate quality impact Epi quality

Without Candela Inspection

Incoming SiC Substrates

Incoming wafer inspection

Less sensitive tool

Wafer A

Inspector misses defects

Epi growth

% Yield Impacting (Epi) defects

High Yield loss

With Candela Inspection

Incoming SiC Substrates

Incoming wafer inspection

candela

Wafer A

Additional wafer processing

Incoming wafer inspection

candela

Wafer A

Epi growth

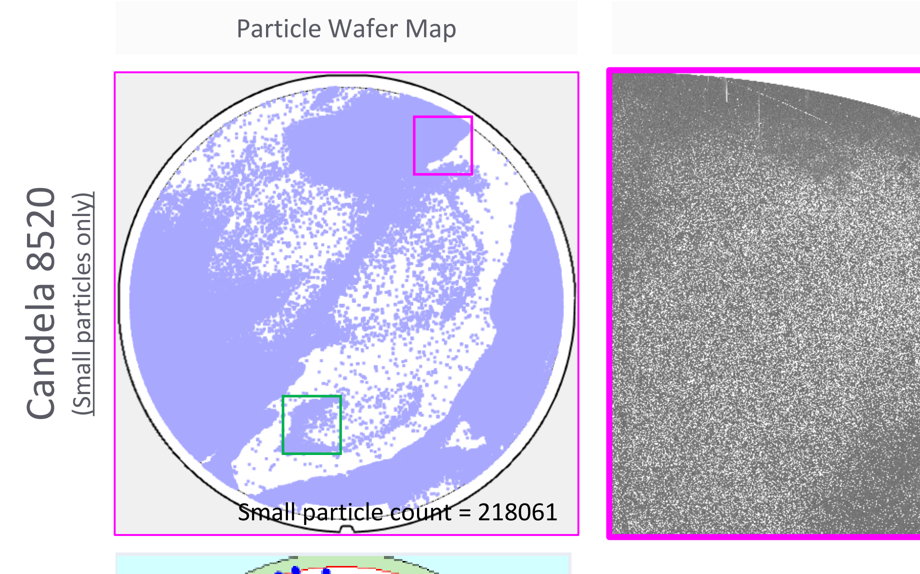
% Yield Impacting (Epi) defects

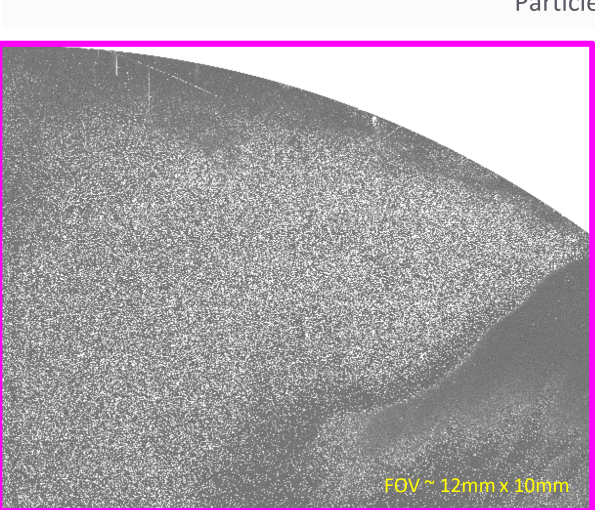
New Process Step and Inspection Point using Candela introduced

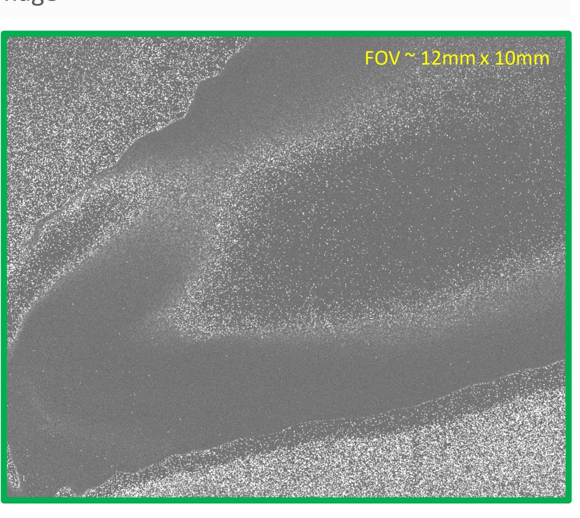
Candela 8520 enables high particle detection sensitivity for **detection** of **excursions** related to clean and dry process

Particle Wafer Map | Particle Image

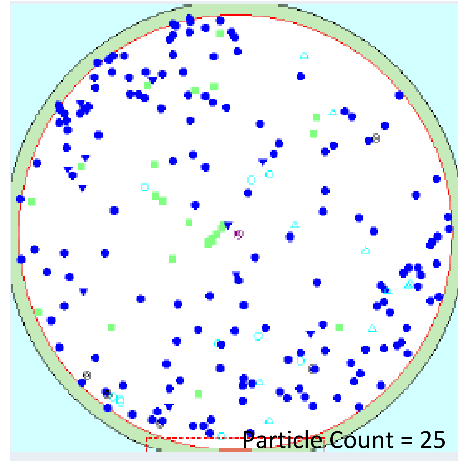
Candela 8520 (Small particles only)







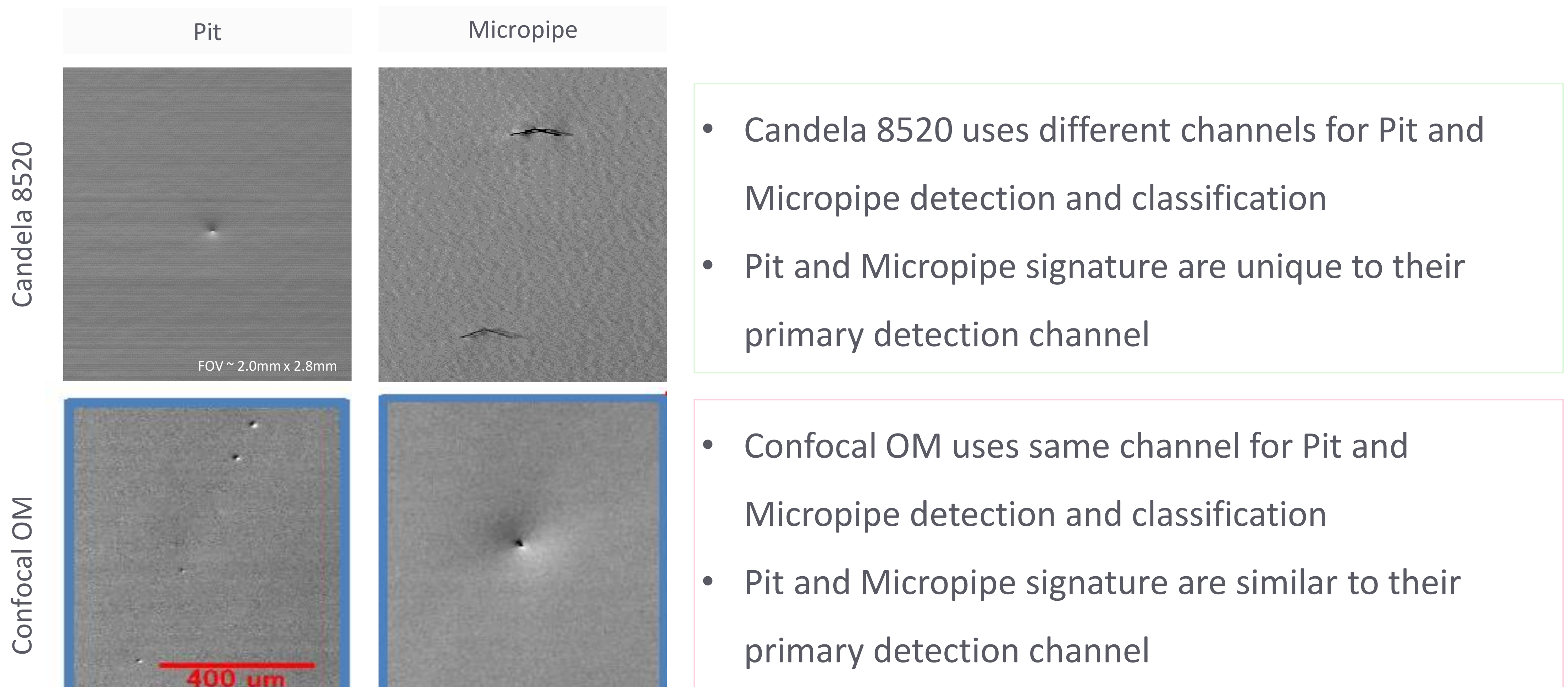
Confocal Technology (All particles)



Customer Feedback:

- Candela 8520 “small” particle count >> Confocal OM “all” particle count
- Confocal OM missed particle excursion → Clean and Dry process issue was not detected
- Candela 8520 inspection sensitivity > Confocal OM

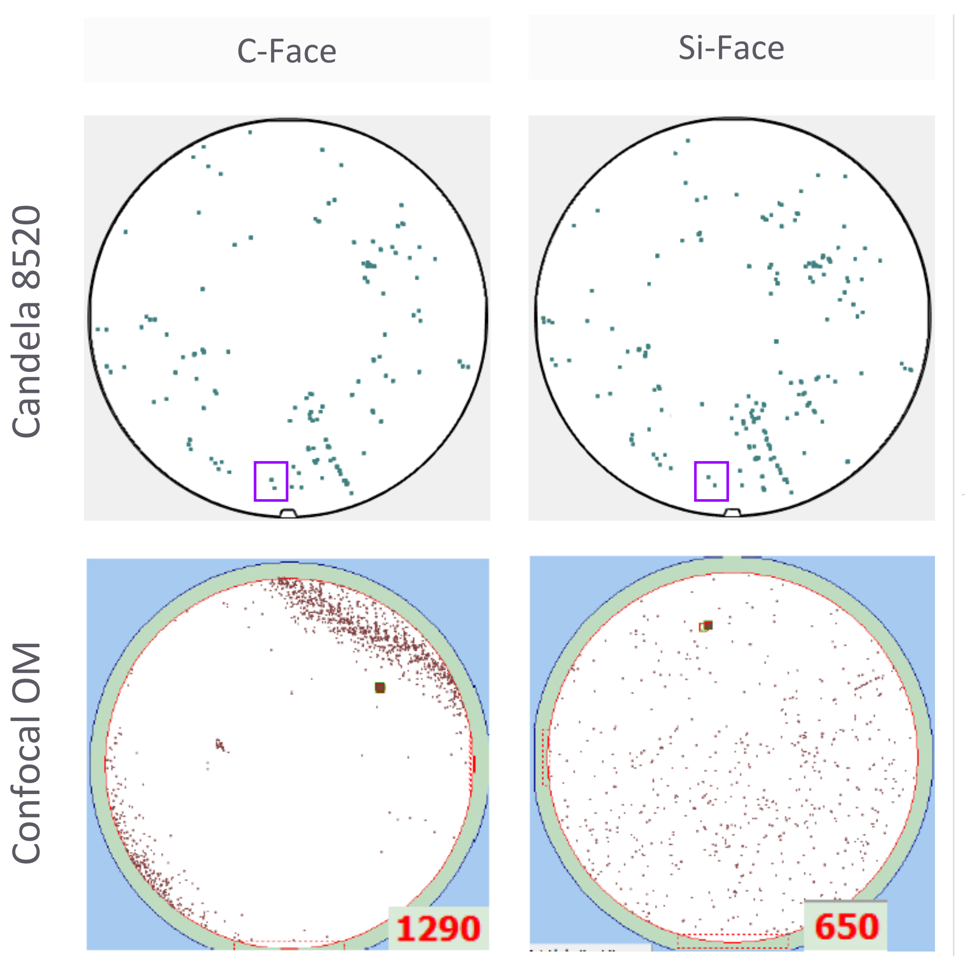
Candela 8520 provides clear **distinction** between **Pits** and **Micropipes** on SiC substrates



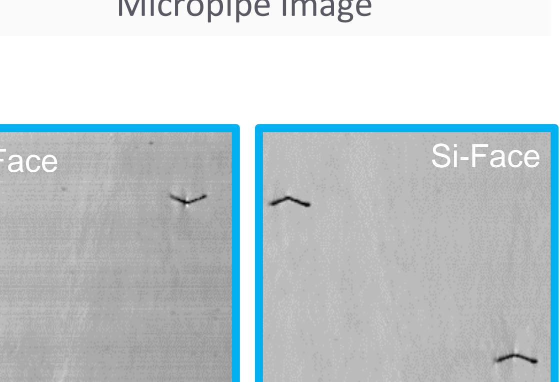
KLA

Head-to-Head comparison

Candela 8520 Micropipe detection correlates with baseline



Micropipe Image



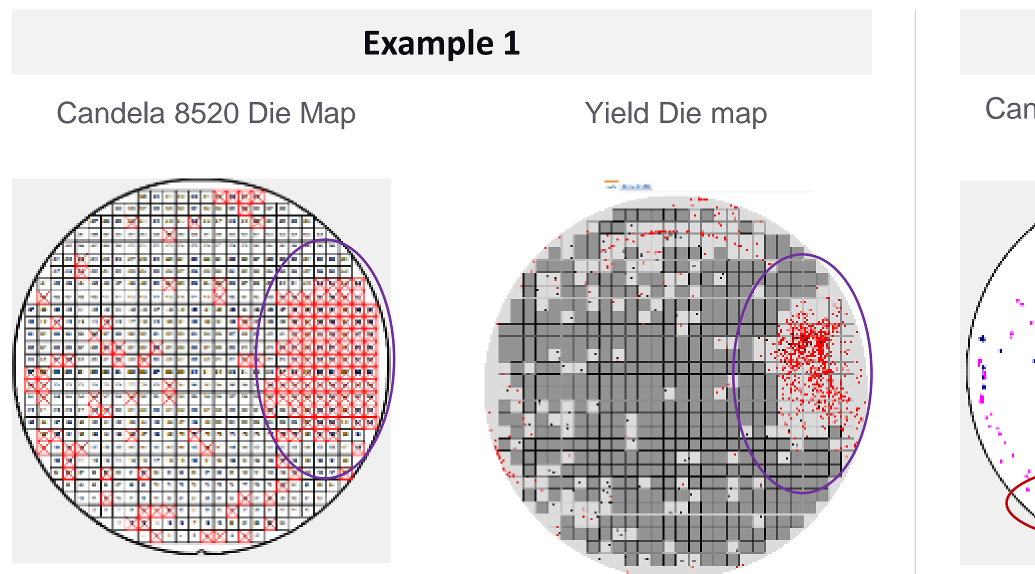
Performance Comparison

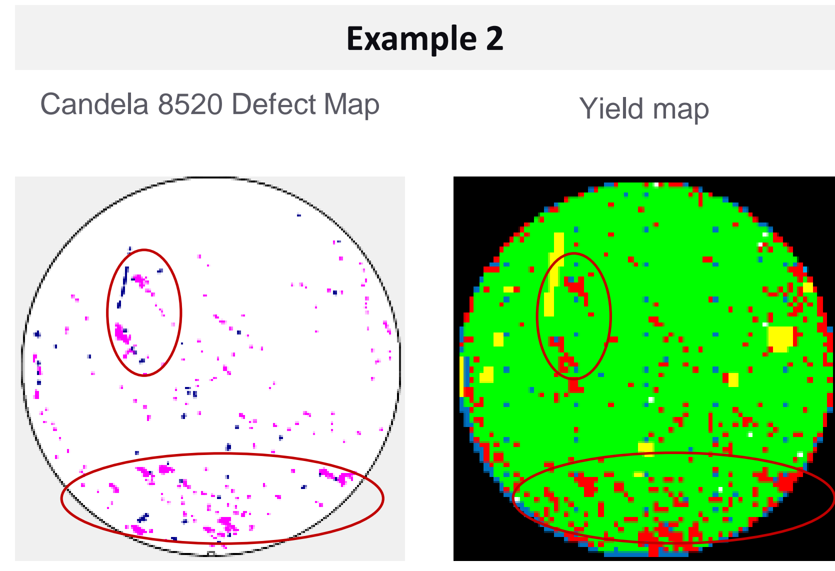
	C-Face	Si-Face
Baseline	~ 130	~ 130
8520	135	153
Confocal	1290	650

Customer Feedback:

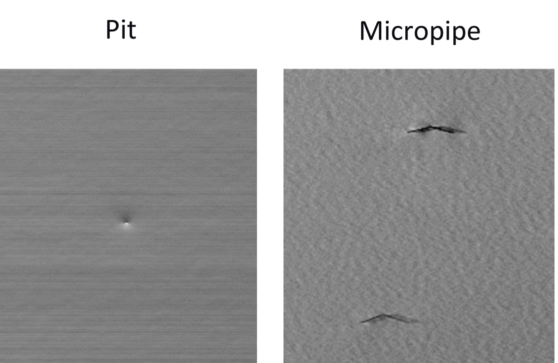
- Candela 8520 has better Micropipe vs Pit classification
- Candela 8520 has better Front Side vs. Back Side correlation for counts and location of micropipe
- Candela 8520 inspection replaced baseline inspection methodology (results on next slide)

Micropipes on SiC substrate are device killers





- **Candela 8520** is able to classify **micropipes** accurately and **distinguish** them from **pits**
- **High leakage current** observed on devices with micropipes
- **100% correlation** observed between **micropipes** on SiC substrates & device **yield**



KLA

Candela 8520 provides fast automated non-destructive mapping of Micropipes for SiC makers

key SiC makers replace OM using Candela 8520 for accurate MP mapping

Inspection Tool	Inspection Output
Polarized Transmission Optical Microscope =	MP signature under PTOM + No Stress Observation + (74ea)
Candela 8520* =	Stress Region / Micropipes + (90ea, 1.25/cm²)

"petal shape" under polarized transmission microscope 50x

Wafers

*qualified by key SiC makers

Unique signature from high resolution imaging enabling convenient defect review

8520 capture 21% more

- *Automated Full Wafer Mapping with defect review feature*
- *Identification of similar MP signatures across sister wafers*

Challenges

- Time-consuming (20mins/4'' by experienced operator)
- Manual counting, map drawing, density calculation. Not suitable for HVM production
- Manpower cost, mis-judgment, human bias
- Limited sensitivity (potentially miss tiny MPs)
- No image traceback/review

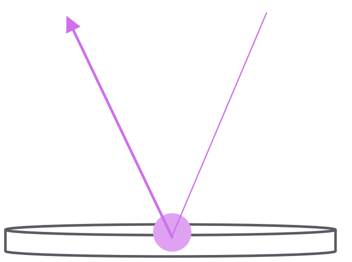
Benefits

- High throghput (2mins/4'')
- Automated MP mapping and density reporting
- Automatic image review
- Separatation of single micropipe vs micropipe chain
- Crystal stress observation
- User-defined edge exclusion
- Save manpower/cost

Lower manufacturing costs by Inspecting with Key Technologies

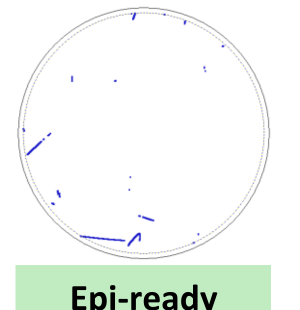
Candela 8520 has superior resolution to capture potential risks in a non destructive way

355nm UV Laser based scatter Channel



Key Technology Enables:
50nm penetration depth into SiC Bulk

SiC Substrate Key Defect:
CMP/Polishing Scratch

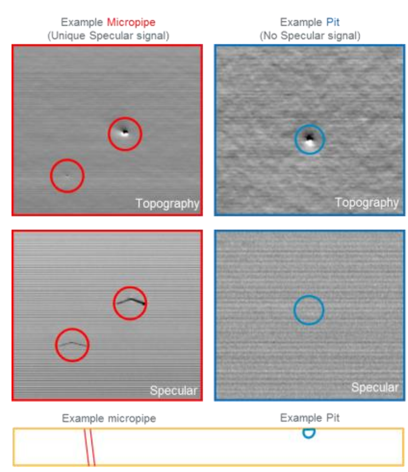


Epi-ready

Marginal

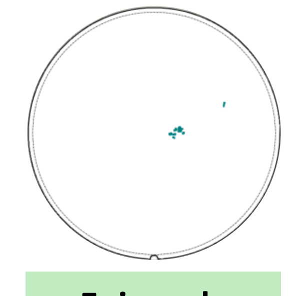
REJECT

405nm Violet Laser based specular channel

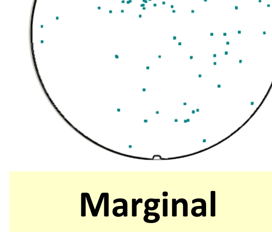


Key Technology Enables:
Non Destructive Micropipe Detection

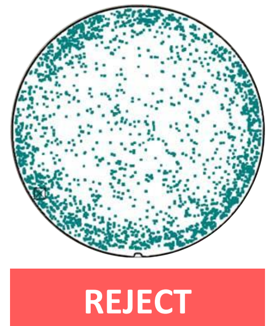
SiC Substrate Key Defect:
Micropipes



Epi-ready



Marginal



REJECT

SiC Process Inspection Points

SiC Boule → Wafer Cutting → Patterning → Power Device

Inspection Points

Packaging

Ship

Xtal Growth | Slicing | Lapping | Polishing | Cleaning | Epitaxy | Wafer Fabrication | Thinning & Dicing | Test & Sorting

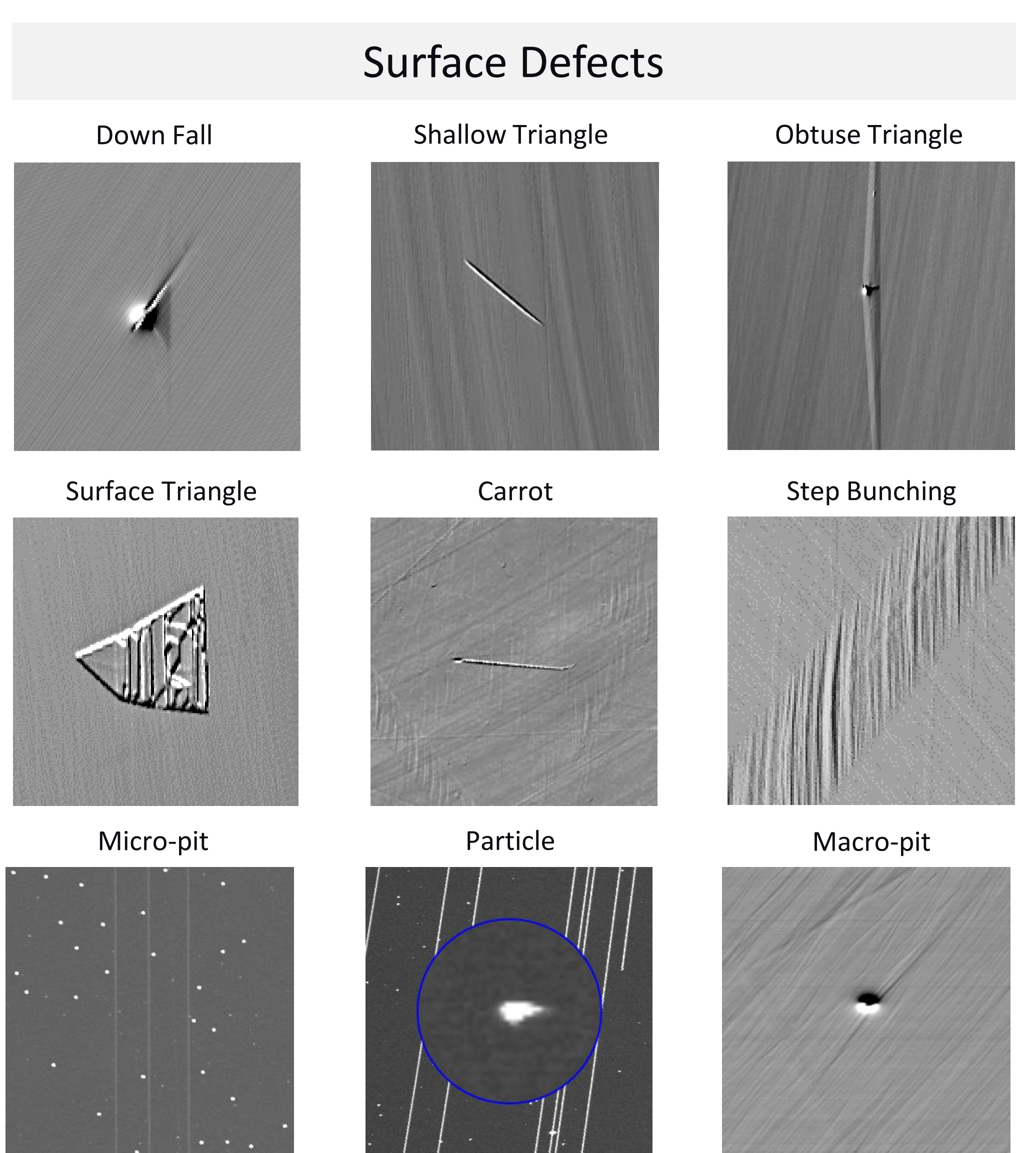
Substrate Quality Control
- SiC Material Defects
- Substrate Vendor Comparison
- IQC on Substrates

Epi Growth Process Control
- **Epi defect inspection**
- **Substrate to Epi correlation**
- **Micropit detection**
- **MOCVD SPC Charts**
- **MOCVD Vendor Comparison**

In-Line Production Monitoring
- Reflective Layer Monitoring
- Tool Qualification
- Process Monitor

Candela 8520 has integrated surface & PL technologies to help Optimize SiC Epitaxy

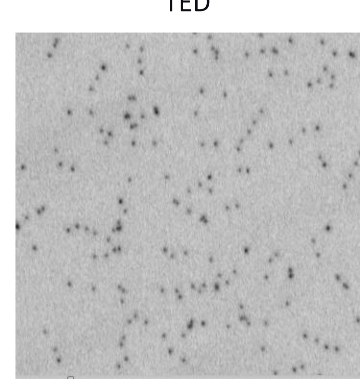
Surface Defects



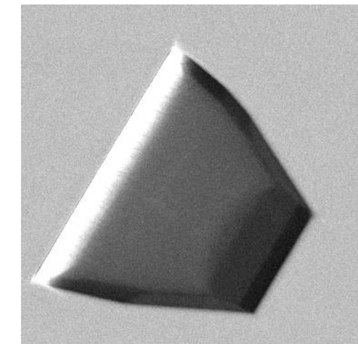
Photoluminescence Defects

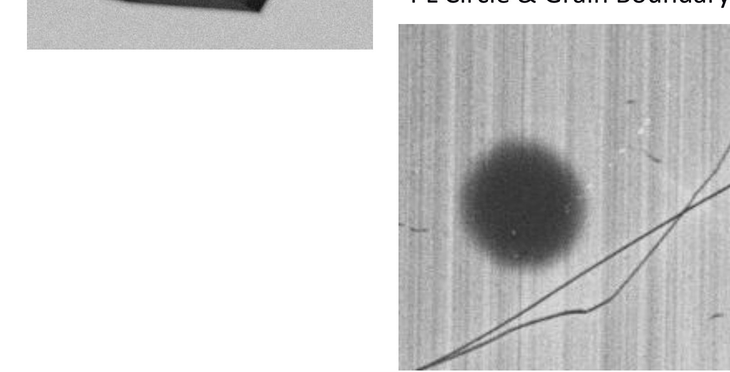
Single & Bar Stacking Fault

TED



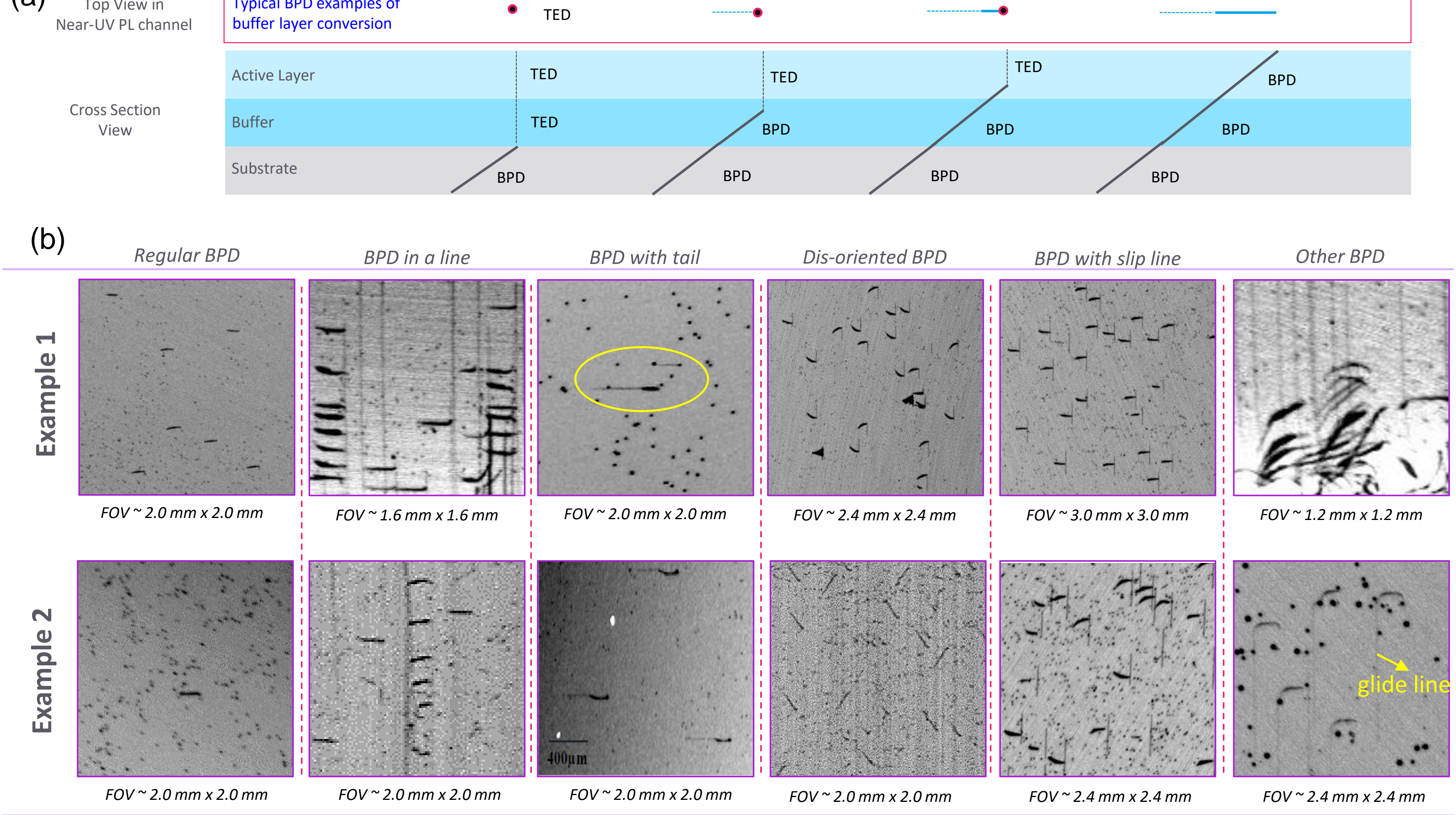
Crystal Defect





KLA

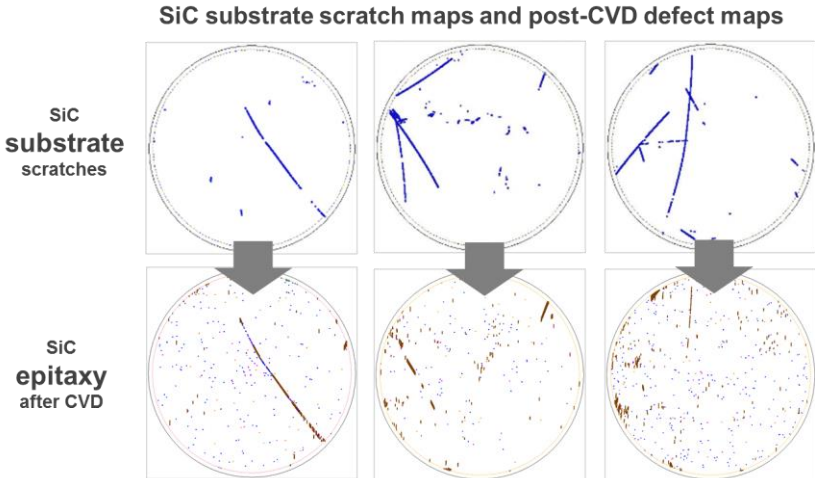
Candela 8520 provides direct feedback for optimization of buffer layer engineering by high resolution imaging of BPD's



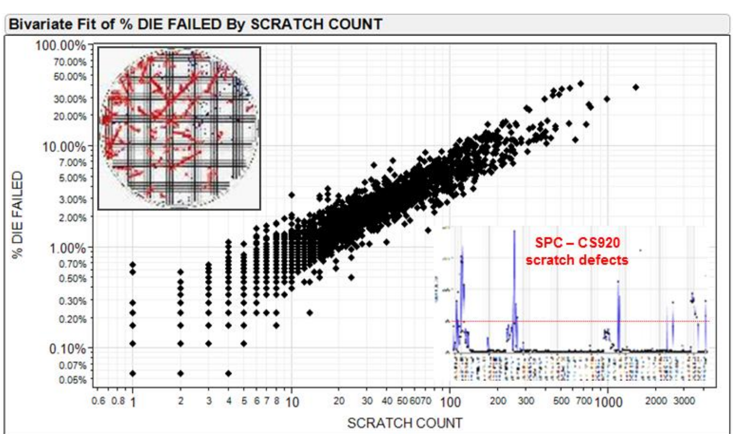
KLA

SiC substrate scratches impact Power Device Yield

Why power device makers are concerned with faint scratches ..

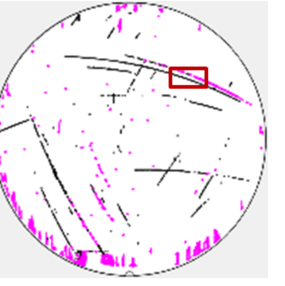


CMP scratches root-cause of epi defects

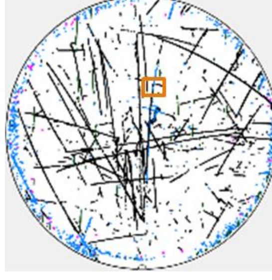


SiC vendor quality impacts production yield

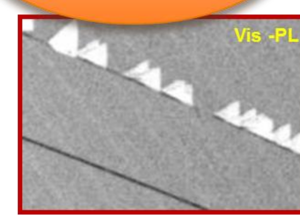
- non-optimized SiC CMP process estimated at **~10% yield loss**
- scratches / CMP polishing residue → stacking faults and **poor device reliability**

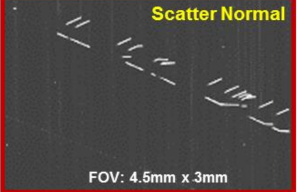


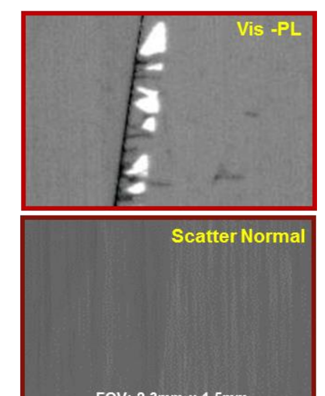
SiC epitaxy defects root-cause → substrate scratches



SiC epitaxy defects root-cause → substrate scratches







Substrate to Epi correlation

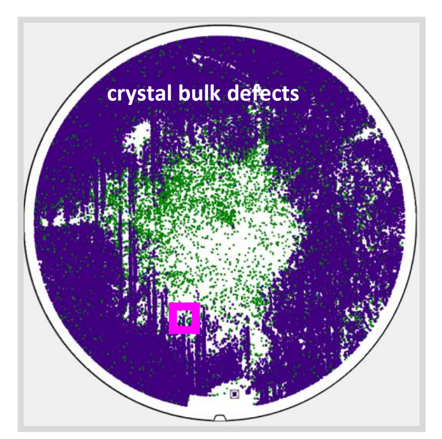
SiC substrate quality impacts BPD orientation post epi growth

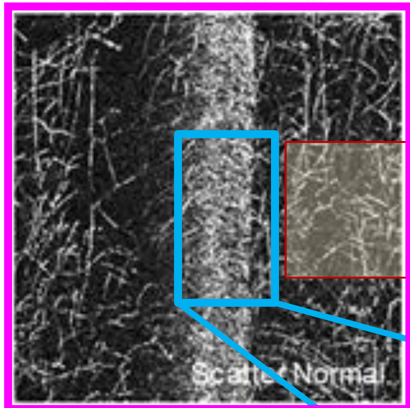
Substrate Vendor	Vendor 1	Vendor 2	Vendor 3
SiC/SiC MOCVD Reactor		Vendor 1	
Epi Thickness		12µm	
BPD Type	Straight, w/o tail	Curved, w/ short tail	Curved, w/ long tail
Typical BPD Count	200~500	800~1000	800~1000
NUV-PL Image Example	FOV ~ 2.8mm x 2.8mm	FOV ~ 2.8mm x 2.8mm	FOV ~ 2.8mm x 2.8mm
Vendor 1 Vendor 2 Vendor 3 Incoming SiC Substrates	Epi wafer 1	Epi wafer 2	Epi wafer 3

KLA

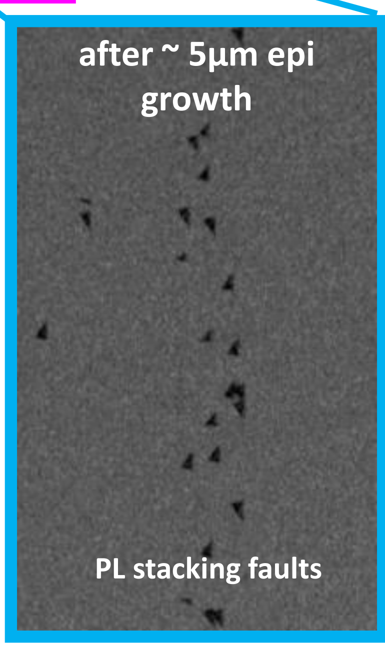
Substrate to Epi correlation

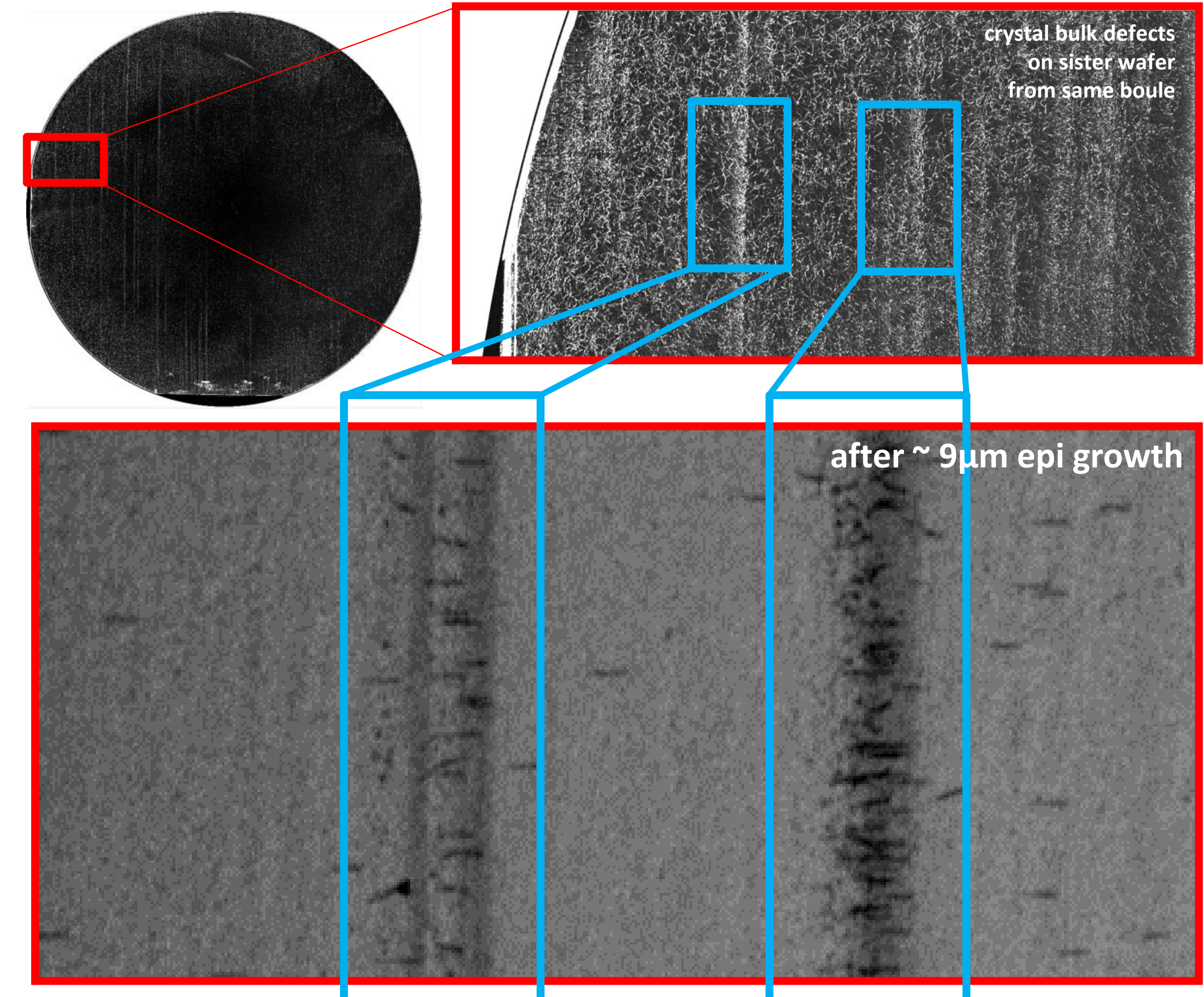
SiC substrate defects found to be root-cause of epi PL triangle stacking faults





← high density of crystallographic defects





defect transfer → substrate to epitaxy

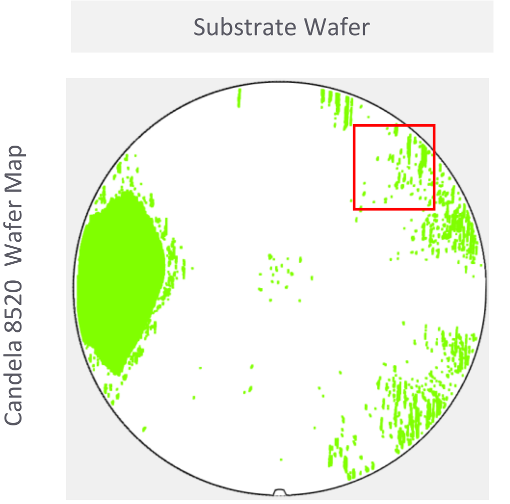
SiC substrate defects found to be **root-cause** of epi PL triangle stacking faults & high density of BPDs

Substrate to Epi correlation

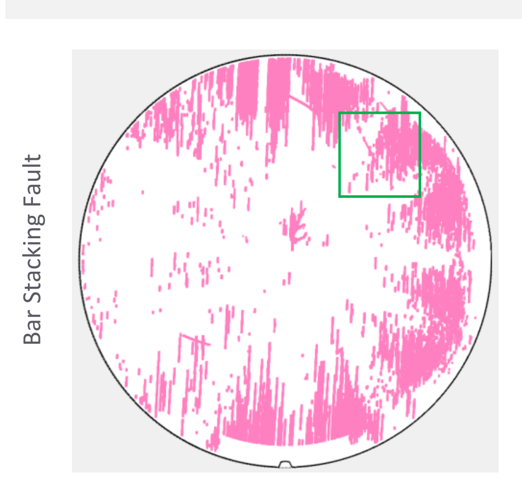
Substrate Stacking Faults → root cause of Epi Stacking Faults

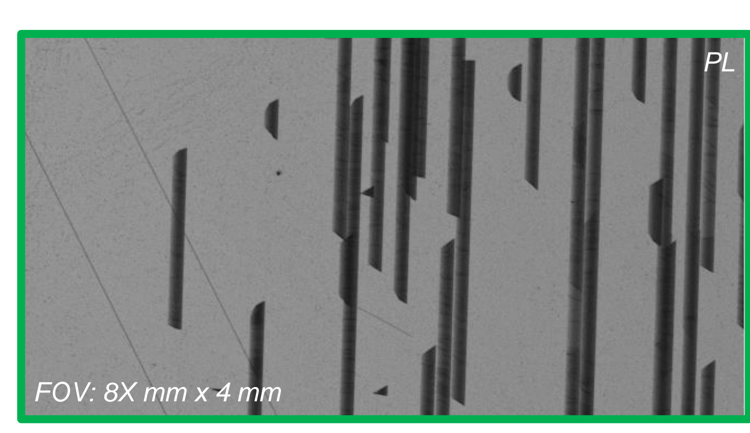
Substrate Wafer	After Epi growth

Candela 8520 Wafer Map

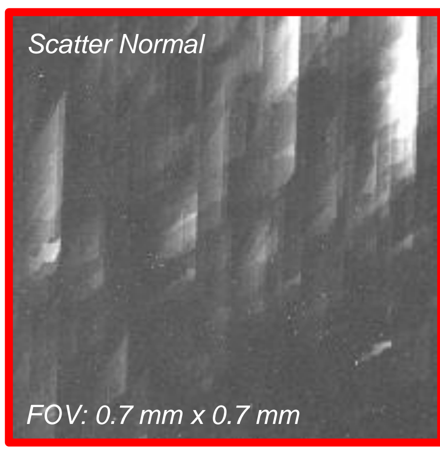


Bar Stacking Fault

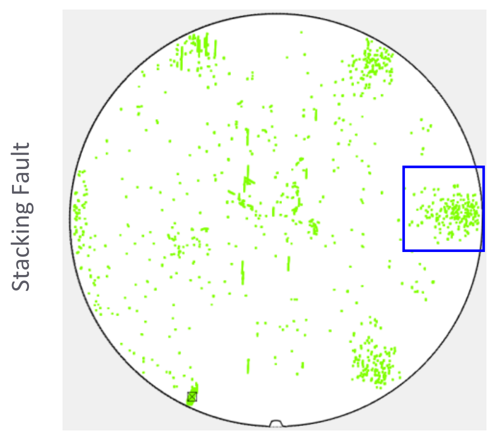


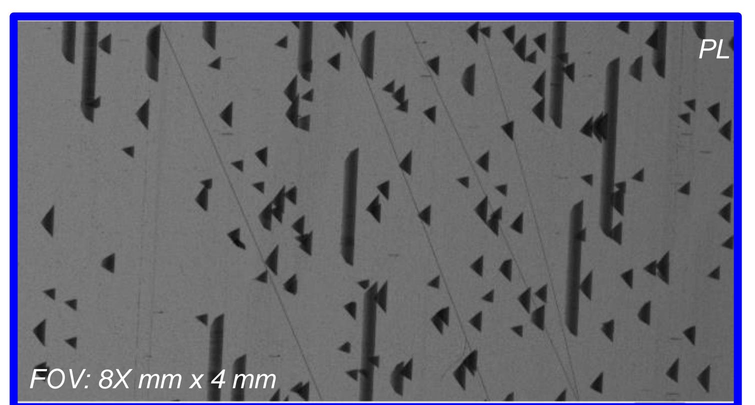


Candela 8520 Image



Stacking Fault



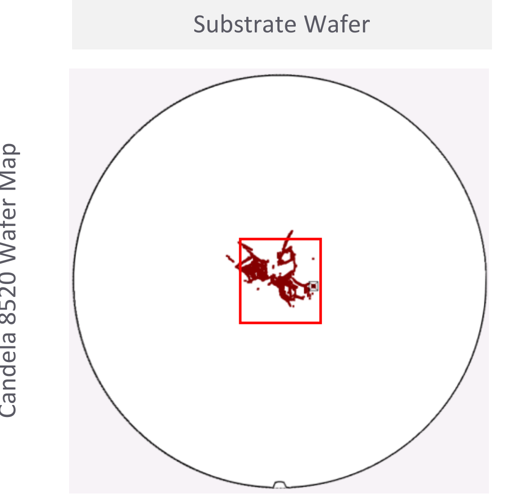


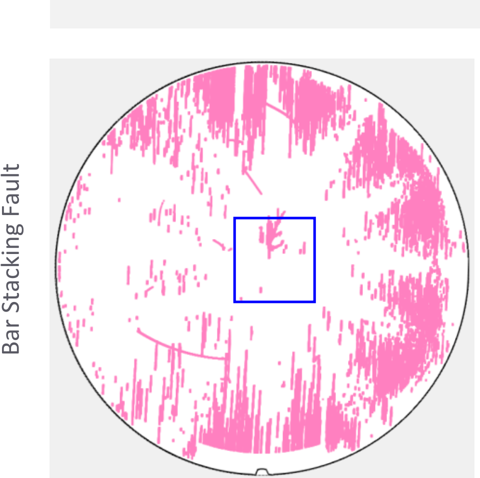
Substrate to Epi correlation

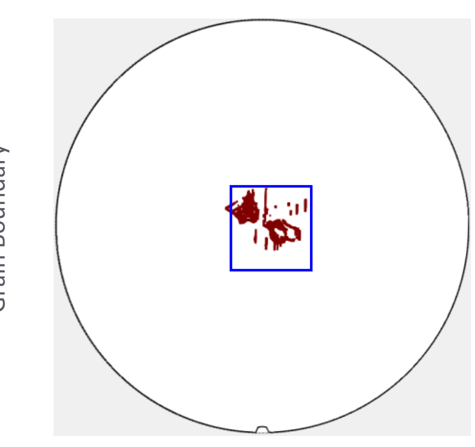
Substrate Grain Boundary propagates post Epi growth

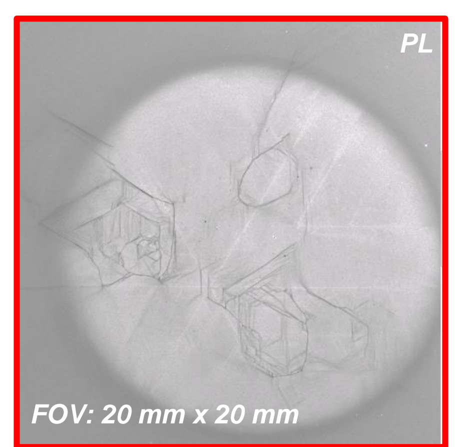
Substrate Wafer

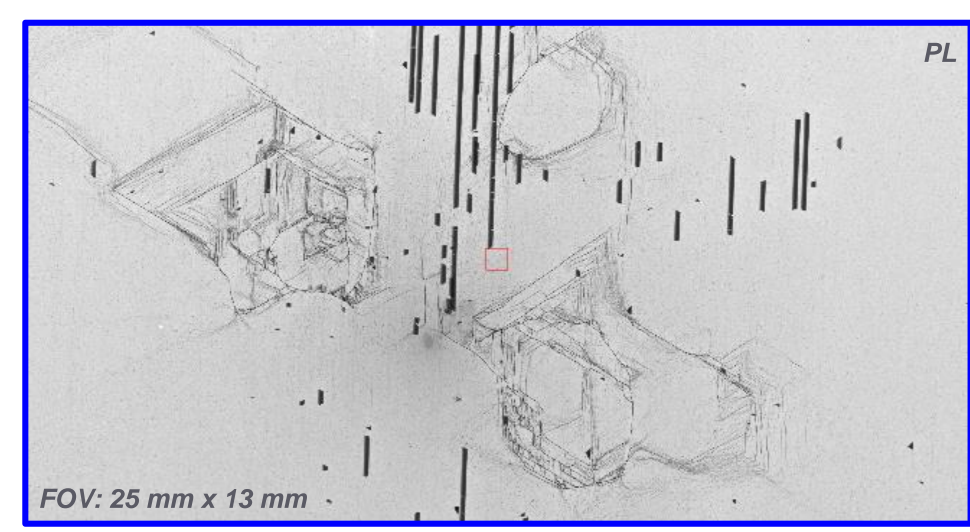
After Epi growth





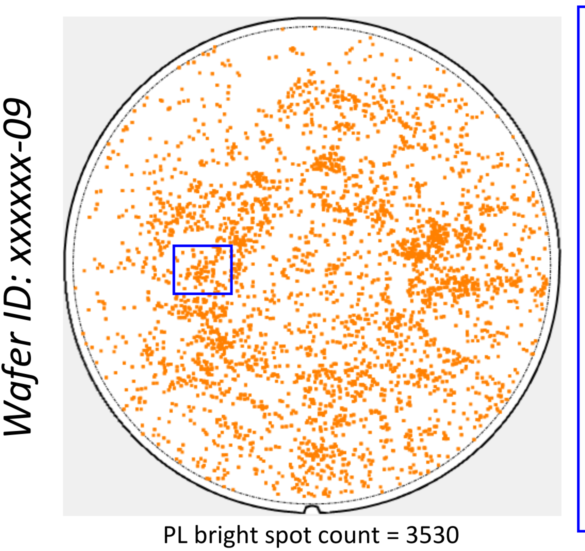




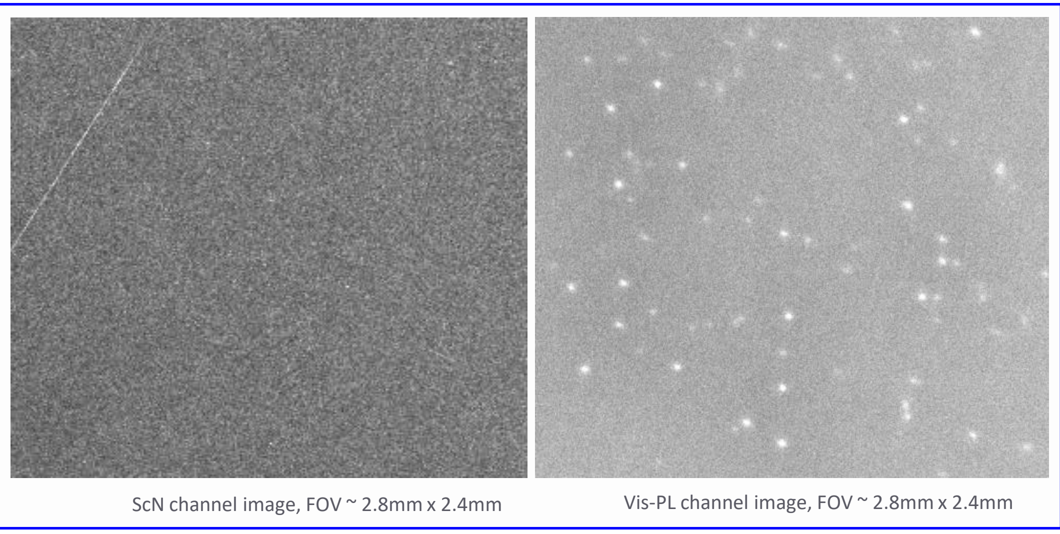


KLA

Substrate PL bright spots are nucleation centers of surface “V” shape killers

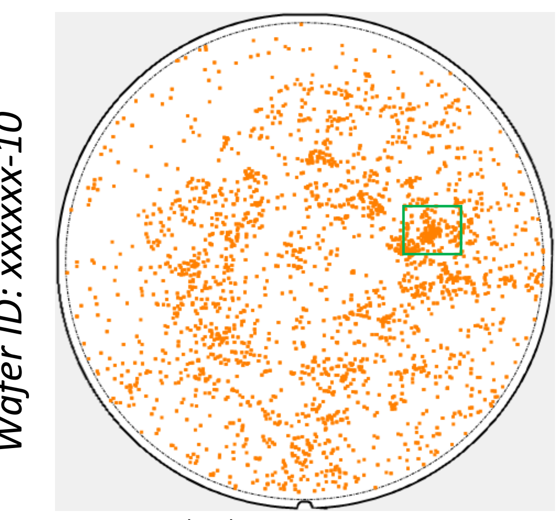


PL bright spot count = 3530

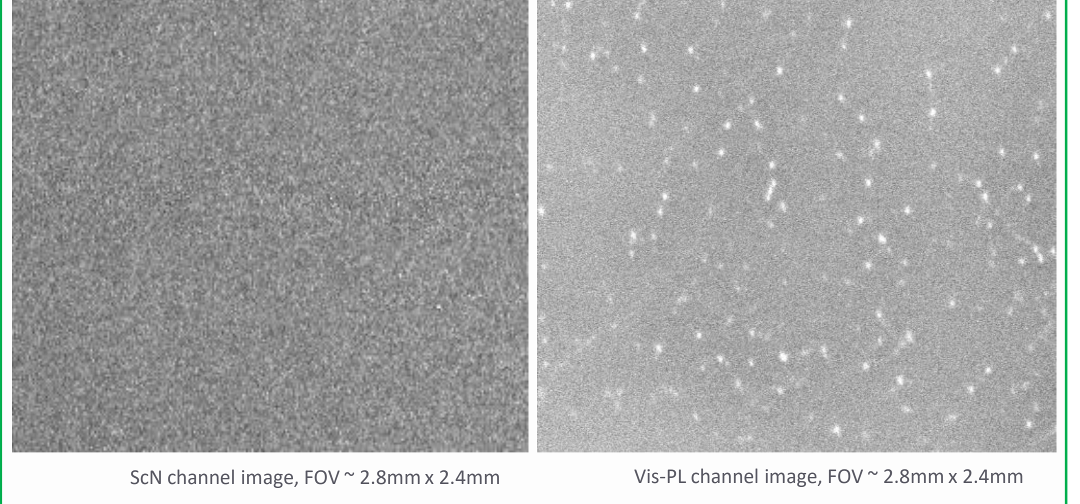


ScN channel image, FOV ~ 2.8mm x 2.4mm

Vis-PL channel image, FOV ~ 2.8mm x 2.4mm



PL bright spot count = 2814



ScN channel image, FOV ~ 2.8mm x 2.4mm

Vis-PL channel image, FOV ~ 2.8mm x 2.4mm

ECS Transactions, 75 (12) 233-237 (2016)
10.1149/07512.0233ecst ©The Electrochemical Society

Characterization of Leakage Causing Visible Epitaxial Defects Nucleating from Crystal Defects in the Substrate

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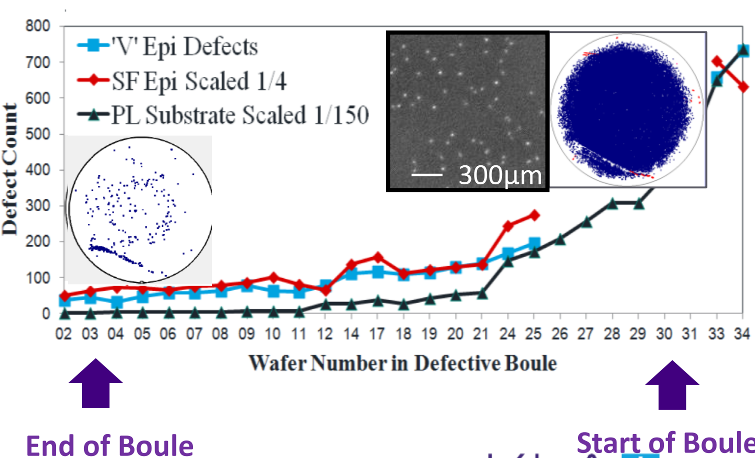
[a] Fairchild Semiconductor, South Portland, Maine 04106, USA
[b] Fairchild Semiconductor, Kista 16440, Sweden

In high volume manufacturing of SiC products, it is important to isolate and eliminate failure mechanisms at the source rather than rely on backend tests. As we enter volume production on 150mm substrates, significant cost and reliability improvements can be achieved if potential sources of defects are identified and removed. In this work we present the electrical effects of an epitaxial ‘V’ type defect, investigate and determine its source to a subset of screw dislocations in the substrate, and provide a way of screening such heavily defective substrates even before epitaxial growth.

PL bright spots are verified to be nucleation centers of surface “V” shape killers and also stacking faults after epitaxy



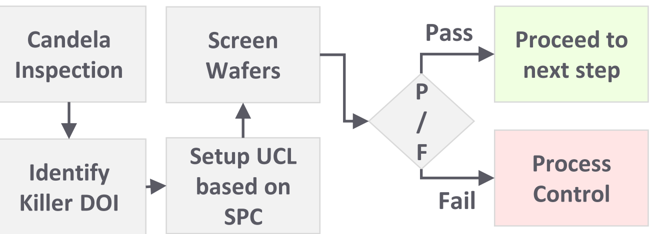
KLA

Candela 8520 enables faster ramp for process development

T1 T2 T3 T4 T5 T6 T7 T8 T9 T10 T11 T12 T13 T14 T15 T16

Process 1

Process Flow:



Process ramp timeline:

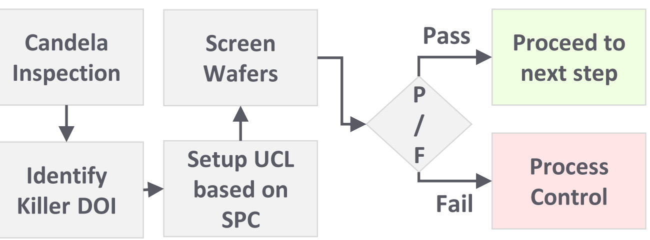
- ~ 2.5 months to reduce defectivity using feedback from SPC based on Candela inspection

Candela 8520 enables faster ramp for process development

T1 T2 T3 T4 T5 T6 T7 T8 T9 T10 T11 T12 T13 T14 T15 T16

Process 1 Process 2

Process Flow:



Process ramp timeline:

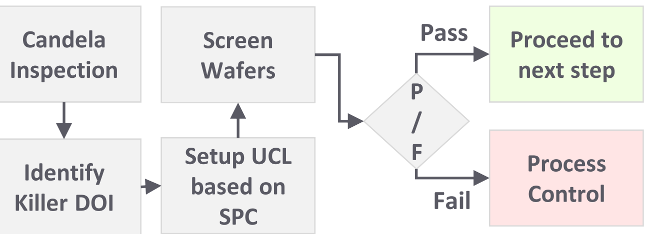
- ~ 2.5 months to reduce defectivity using feedback from SPC based on Candela inspection
- < 2 months for new process ramp based on learning from previous process

Candela 8520 enables faster ramp for process development

T1 T2 T3 T4 T5 T6 T7 T8 T9 T10 T11 T12 T13 T14 T15 T16

Process 1 Process 2 Process 3

Process Flow:



Process ramp timeline:

- ~ 2.5 months to reduce defectivity using feedback from SPC based on Candela inspection
- < 2 months for new process ramp based on learning from previous process
- < 1 month ramp for process 3

Candela 8520 Summary

Defect Detection & Classification

- Simultaneous collection of multiple defect channels
- <100nm particle sensitivity on Silicon
- High sensitivity for scratch detection
- No mandatory edge exclusion
- Simple RBB to bin defects into different categories

Versatility

- Inspection of wafers up to 8 inches in diameter
- Simultaneous Surface & PL inspection
- Multiple-Material Inspection capability
    - SiC Substrate & Epitaxy
    - GaN Substrate & Epitaxy
    - Other Compound Semi materials

Offline Defect Review

- One-click image review to understand Macro defect morphology
- Image review can be done on-tool or in offline software
- KLARF & SECS/GEM compatible

Advanced analysis tools

- Overlay pseudo die grid to understand the % wafer area impacted
- Wafer grading based on PASS/FAIL criteria
- Sized binning of particles
- Defect Contour Mapping

KLA Process Yield Management

You are not just buying a tool, you are also buying yield management know how

Inspection Technology

To meet today's and future demands

SPC Monitoring

Based on defects that matter

TOTAL Defects SPC

Defect count: 0, 1000, 2000, 3000, 4000, 5000, 6000, 7000, 8000

UCL

Wafer No.: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32

Process Killer Defects SPC

Defect count: 0, 200, 400, 600, 800, 1000, 1200, 1400

UCL

Wafer No.: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32

Wafer clean

Non Killer Defects (~63% population)

Small Particle, Large Particle

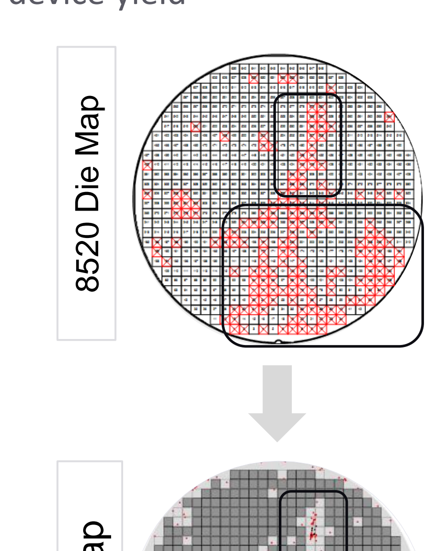
Feedback to MOCVD

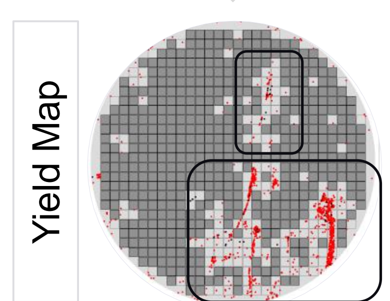
Killer Defects (~37% population)

Pit, Bump, Stain

Defect Engineering

Address process issues that impact device yield





Meet Business Goals

Drive down defectivity

Increase Yield

Thank you!

Instruments Group | Candela

for more information visit www.kla.com