PDF SOLUTIONS™

Analytics for Compound Semiconductors

SiC in Focus

Steve Zamek 6/29/24

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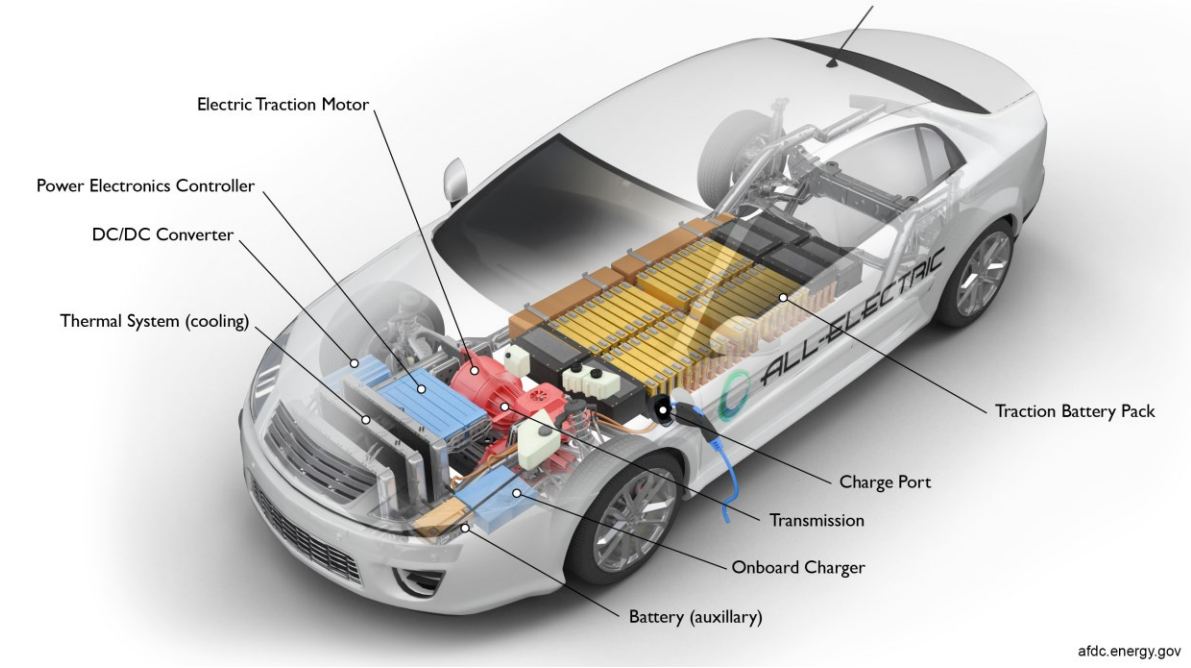
SiC Industry at a Glance

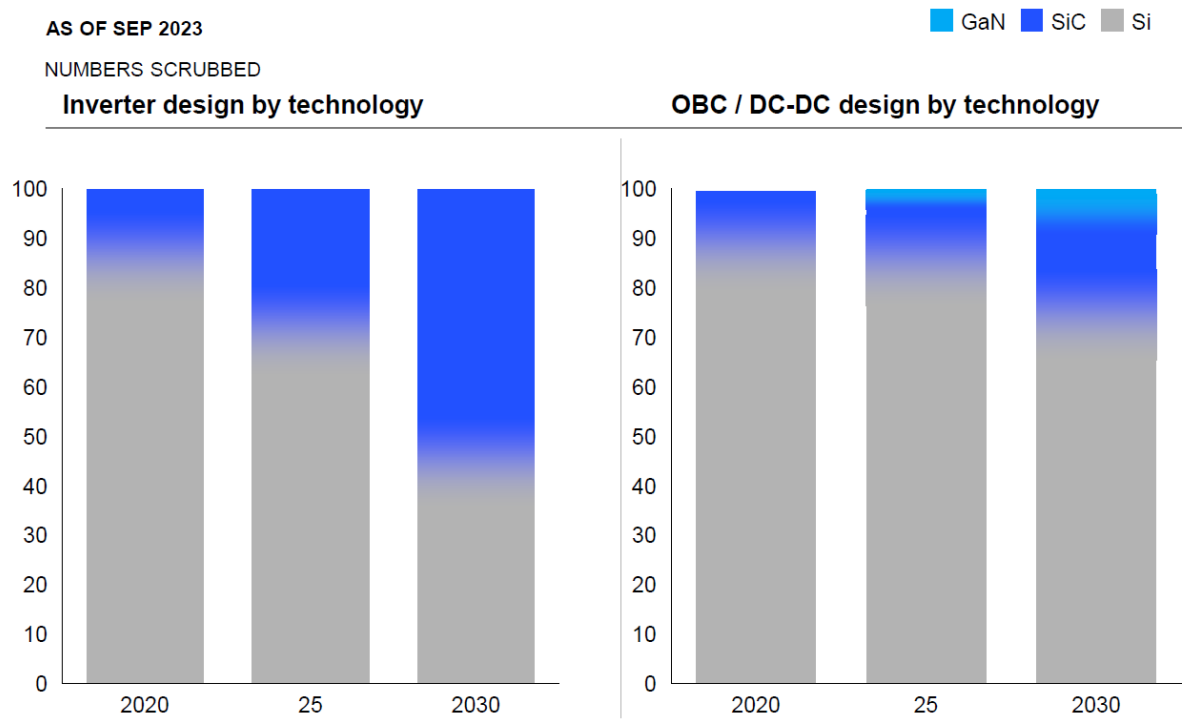
Demand driven mainly by Electric Vehicles

All-Electric Vehicle



source: https://afdc.energy.gov/vehicles/how-do-all-electric-cars-work

Projected 25x demand growth out to 2030

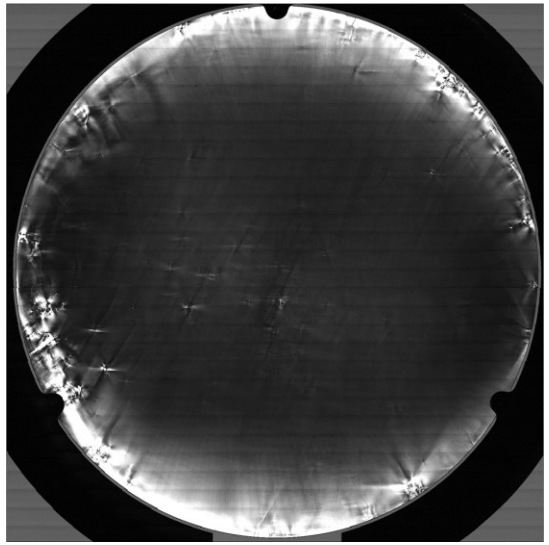


source: McKinsey Center for Future Mobility, Sep 2023

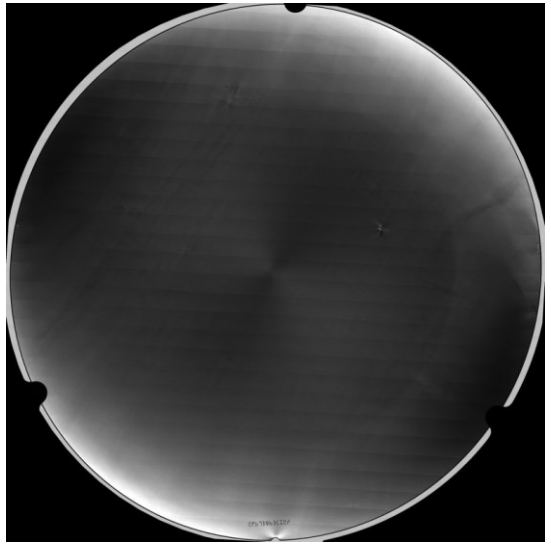
SiC Industry at a Glance

The next 10 years: substrate quality will remain a challenge as the industry is moving to 200 mm wafers

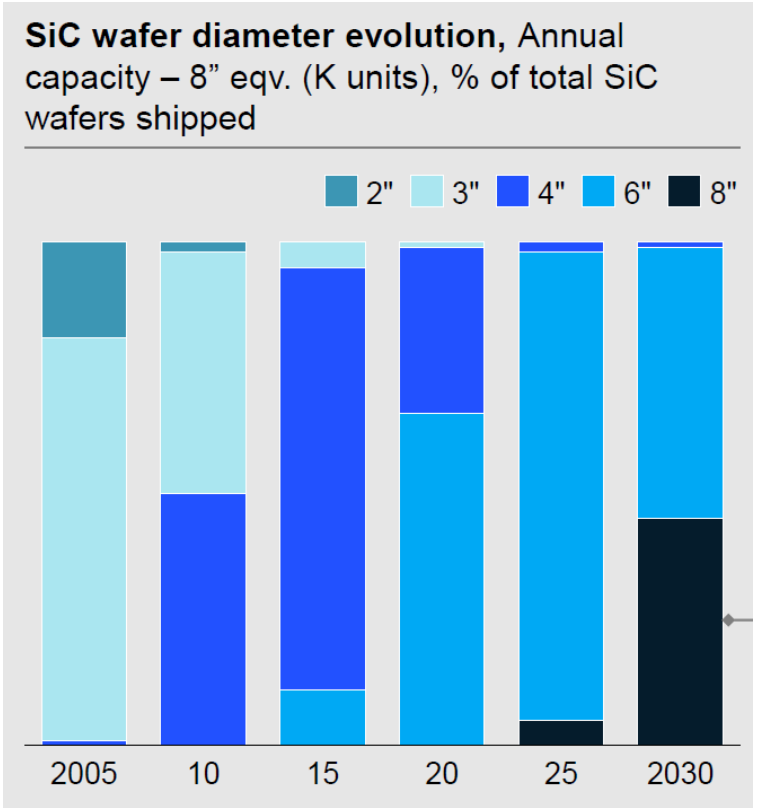
200 MM WAFER; XPOL IMAGE: 2019



200 MM WAFER; XPOL IMAGE: 2022



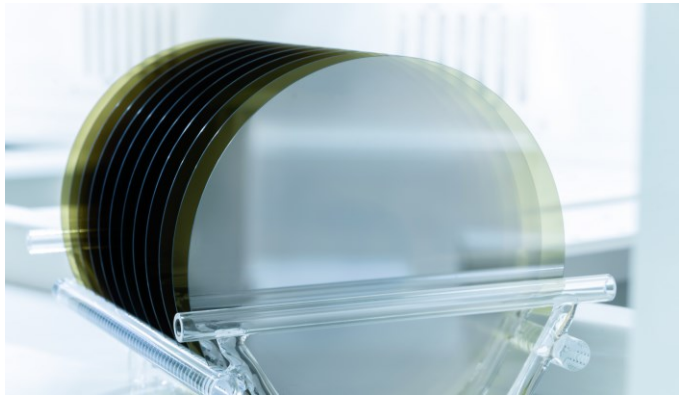
source: Wolfspeed, SEMI Webinar, May 2023



source: McKinsey Center for Future Mobility, Sep 2023

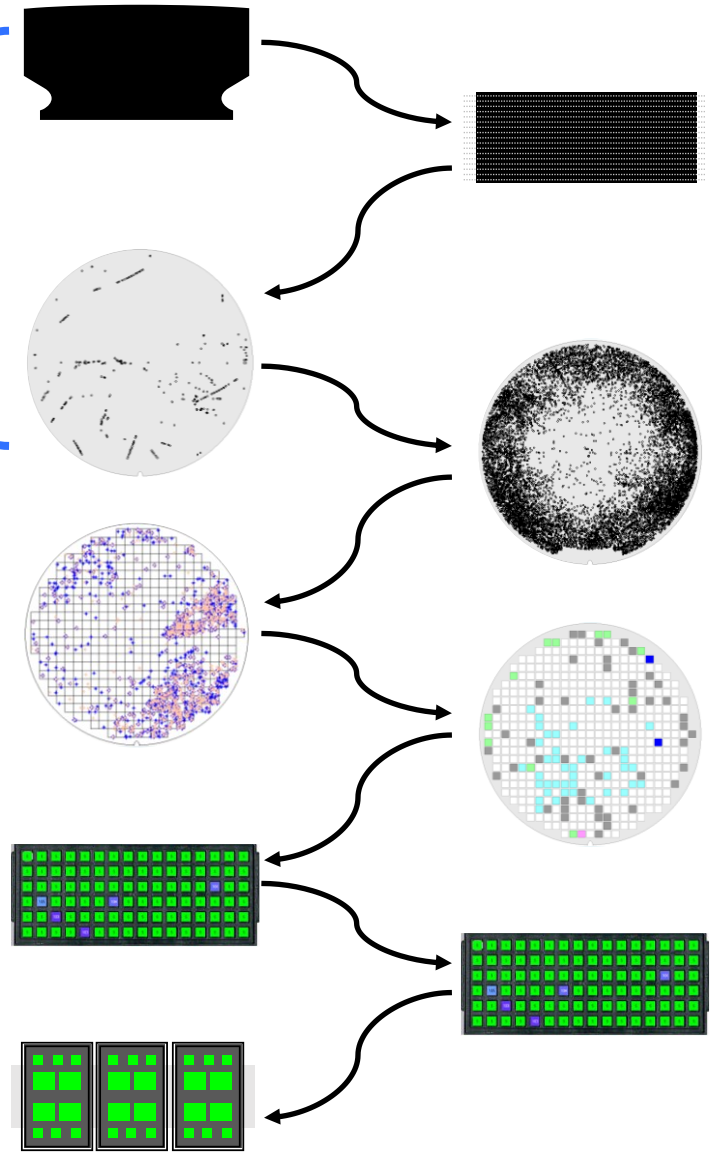
SiC Manufacturing Process Flow

source: CompoundSemiconductors.net, 2017



source: SICC, 2024

>30%
of the final
product cost

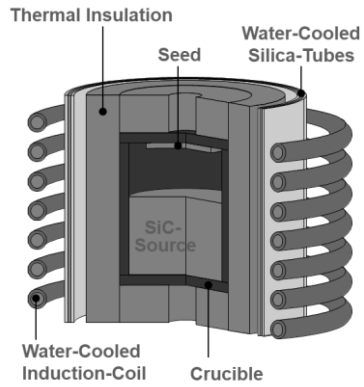


- Boule Growth
- Cutting
- Grind / Polish
- Epitaxy
- Wafer Frontend
- Backside Process
- Wafer Burn-In
- Electrical Sort
- Assembly
- Final Burn-In
- Final Test

Challenges in SiC Manufacturing

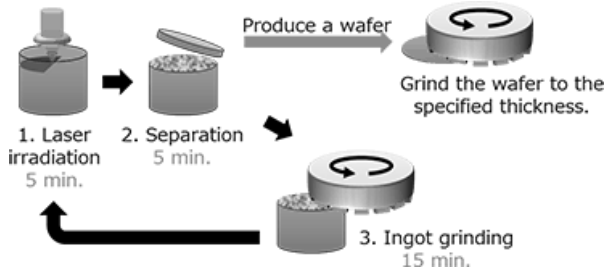
SiC poses unique challenges to manufacturers with high defectivity at all steps

PVT sublimation growth; very slow



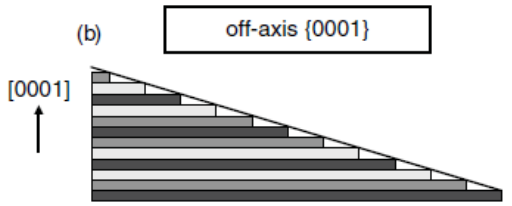
source: ROHM, 2018

Laser or SmartCut (vs wire-saw)



source: DISCO

Off-axis step-flow CVD; very thick epi



source: Kimoto & Cooper, 2014

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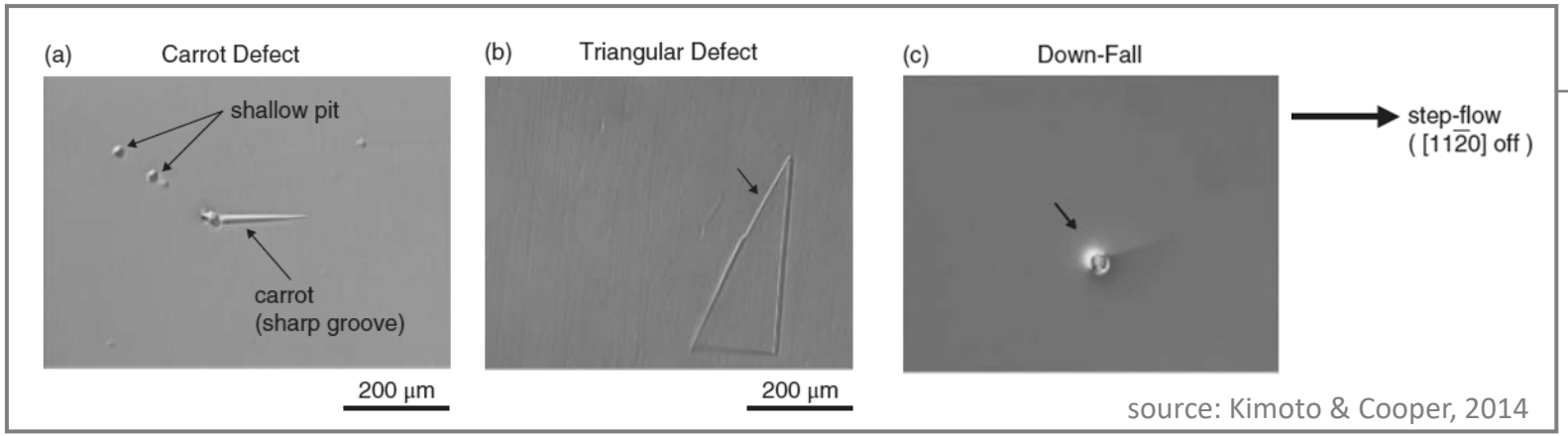
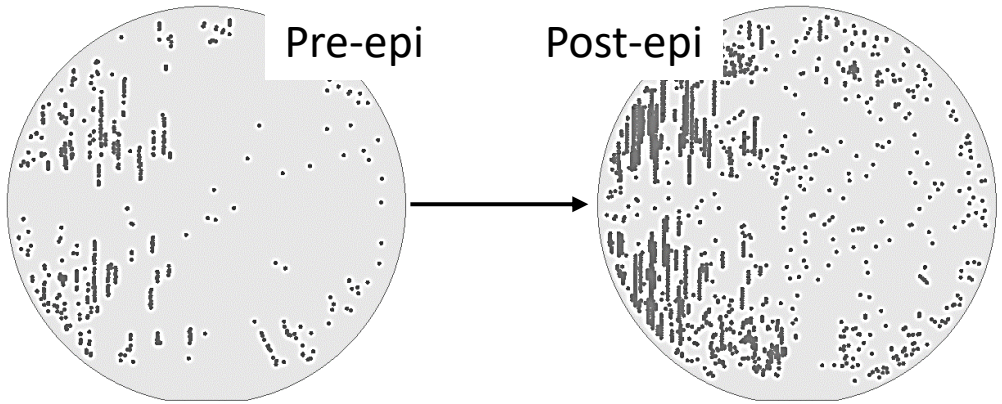
Unique Substrate Defects

Extended boule defects

- Micropipe
- Threading screw dislocation (TSD)
- Threading edge dislocation (TED)
- (Perfect) Basal plane dislocation (BPD)





Defect Inspection
→ **Defect Analytics**
→ **Yield Impact**
→ **Substrate Grading**

- Boule Growth
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Who We Are

Top 50 Equipment suppliers use Cimetrix by PDF for connectivity

Top 6 Foundries Run on PDF Solutions Technology

18 of Top 20 Semi Companies use PDF Solutions Products

>55K Fab tools connected using Cimetrix

>40K process tools under PDF process control across the ecosystem

>350 customers in **20** countries in Fabless, IDM, Foundry, OSAT, and System

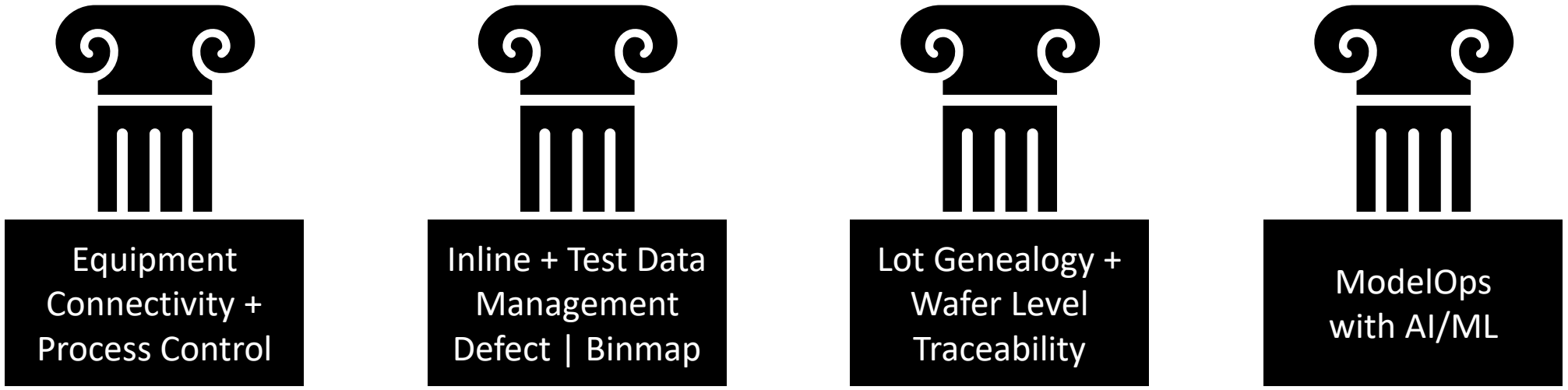
Leading solution for die traceability through the supply chain

Fastest growing company in manufacturing test operations

Our Solutions for SiC Manufacturing Analytics

"SiC is where silicon was decades ago…" → **Accelerate your development with analytics**

Solutions for Silicon Carbide Manufacturing



How We Do It

Proven track-record of interfacing with majority of Manufacturing Execution Systems

Material Hierarchy	Meta Data	Equipment History
Technology	Equipment	Equipment
Family	Operator	TrackIn/Out
Process	Program	Recipe
Product	Recipe	Operator
Source Lot	Date/Time	Chamber
Lot	Process Flow	Rework
Wafer #	Stages	Reticle
Die	Steps	

CamStar
PROMIS
Oracle
IBM Si View
WorkStream
FACTORYWorks
StationWorks
Wonderware
Miracom
APEX
…

exensio

Inline Data
Defect & Metrology

Equipment Sensor Data (FDC)

Electrical Data:
PCM | WAT | Binmap

Assembly Data
Die Level Traceability | E142

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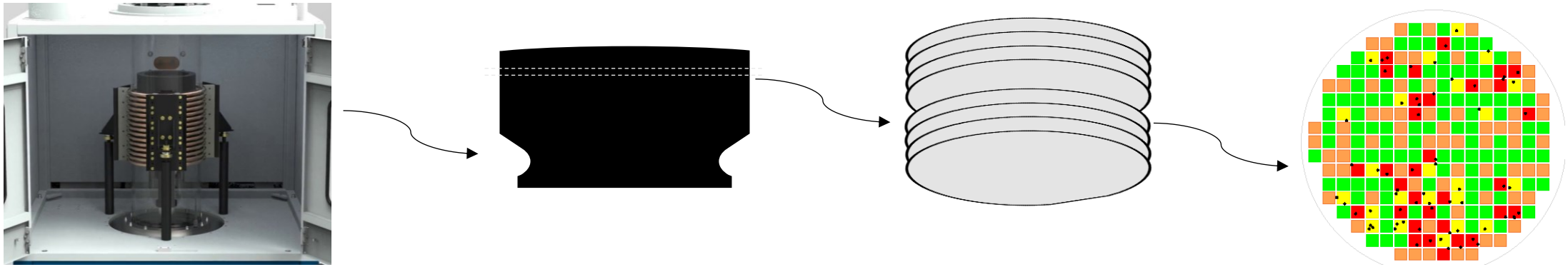
Big Data Manufacturing Analytics platform

Exensio™ Equipment Process Control for SiC



Bring all data under one roof
Use modern data analytics

exensio

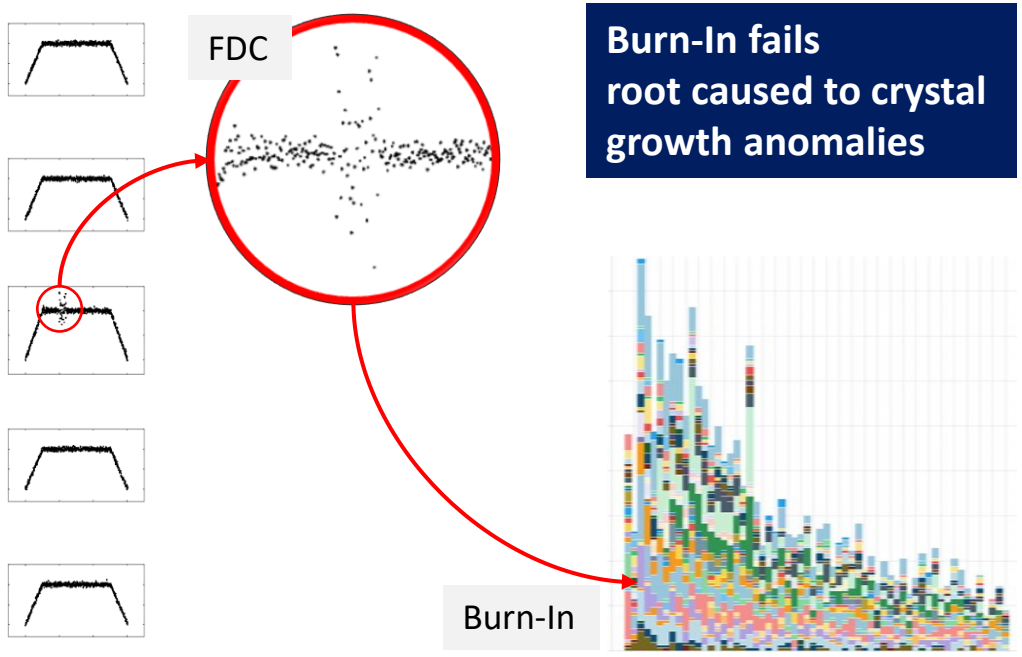
Establish correlations
Identify root-cause of low yield

Deployment Examples in SiC Manufacturing

IDM "C":
True End-to-End Deployment

IDM "B":
Fab, Sort & Assembly

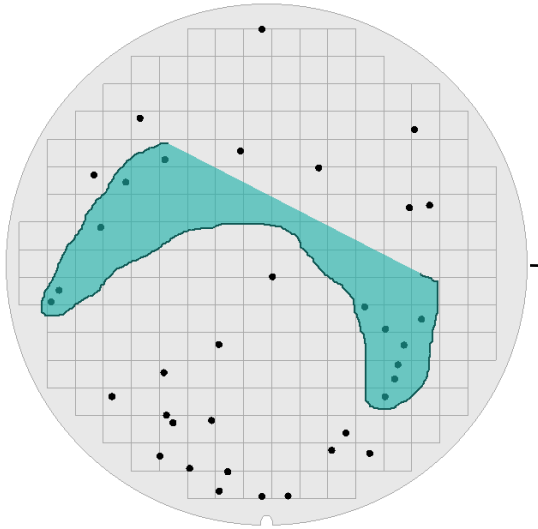
IDM "A":
Exensio Manufacturing Analytics – Fab only

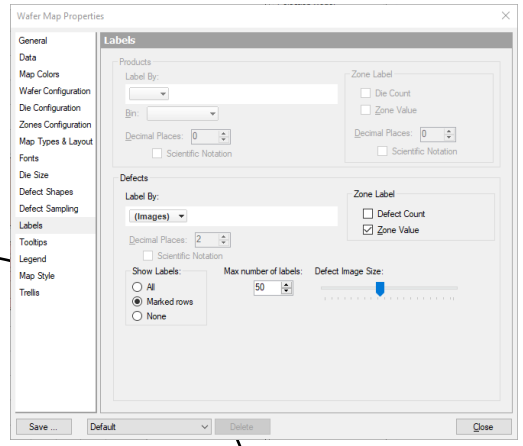


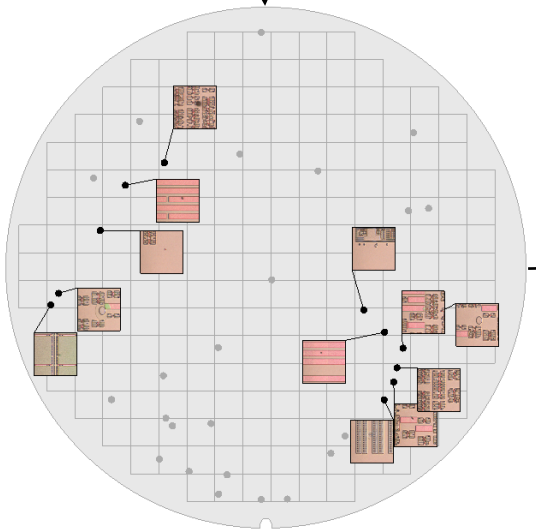
Burn-In fails root caused to crystal growth anomalies

'boule' & Substrate → Epi → Wafer Processing → Wafer Test → Packaging Assembly → Burn-in & Final Test

Defect Management Tools

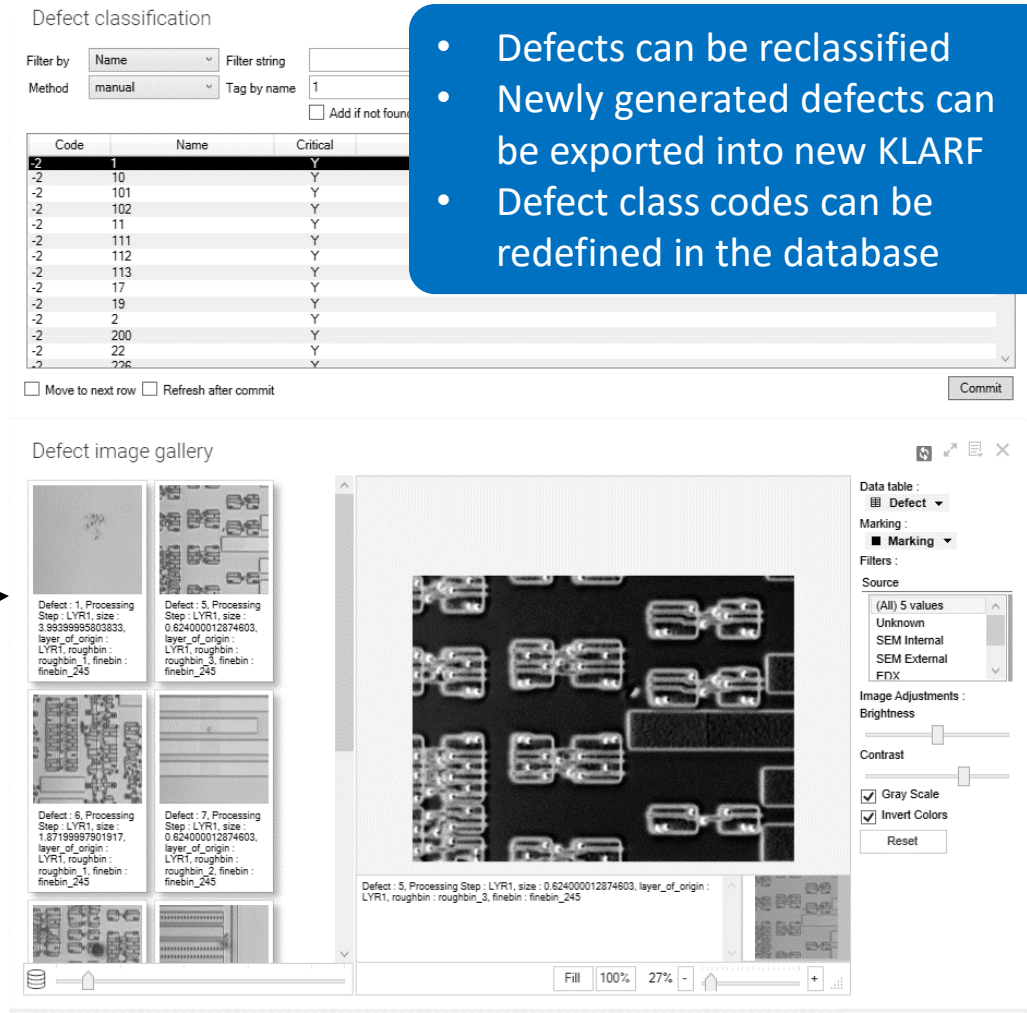






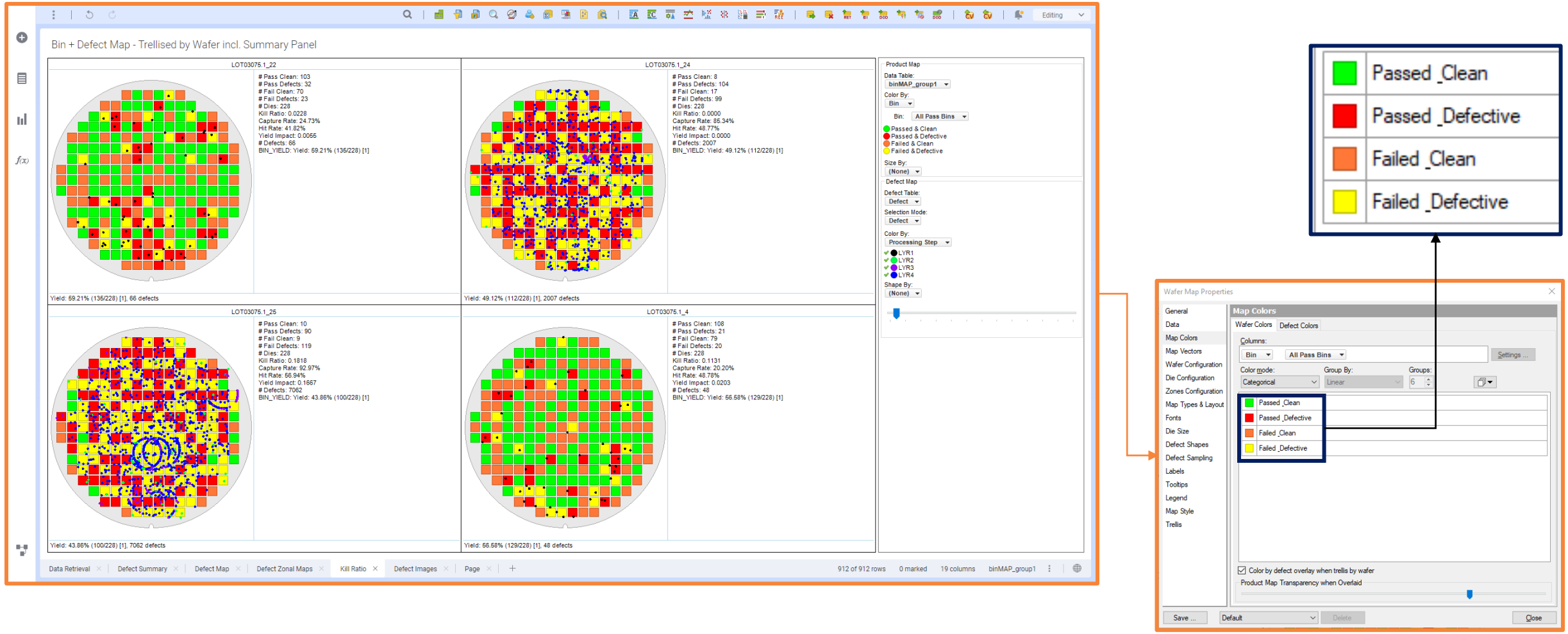
Powerful tools:

- Selections
- Markings
- Labeling
- Sampling



- Defects can be reclassified
- Newly generated defects can be exported into new KLARF
- Defect class codes can be redefined in the database

Defect | Binmap Overlays

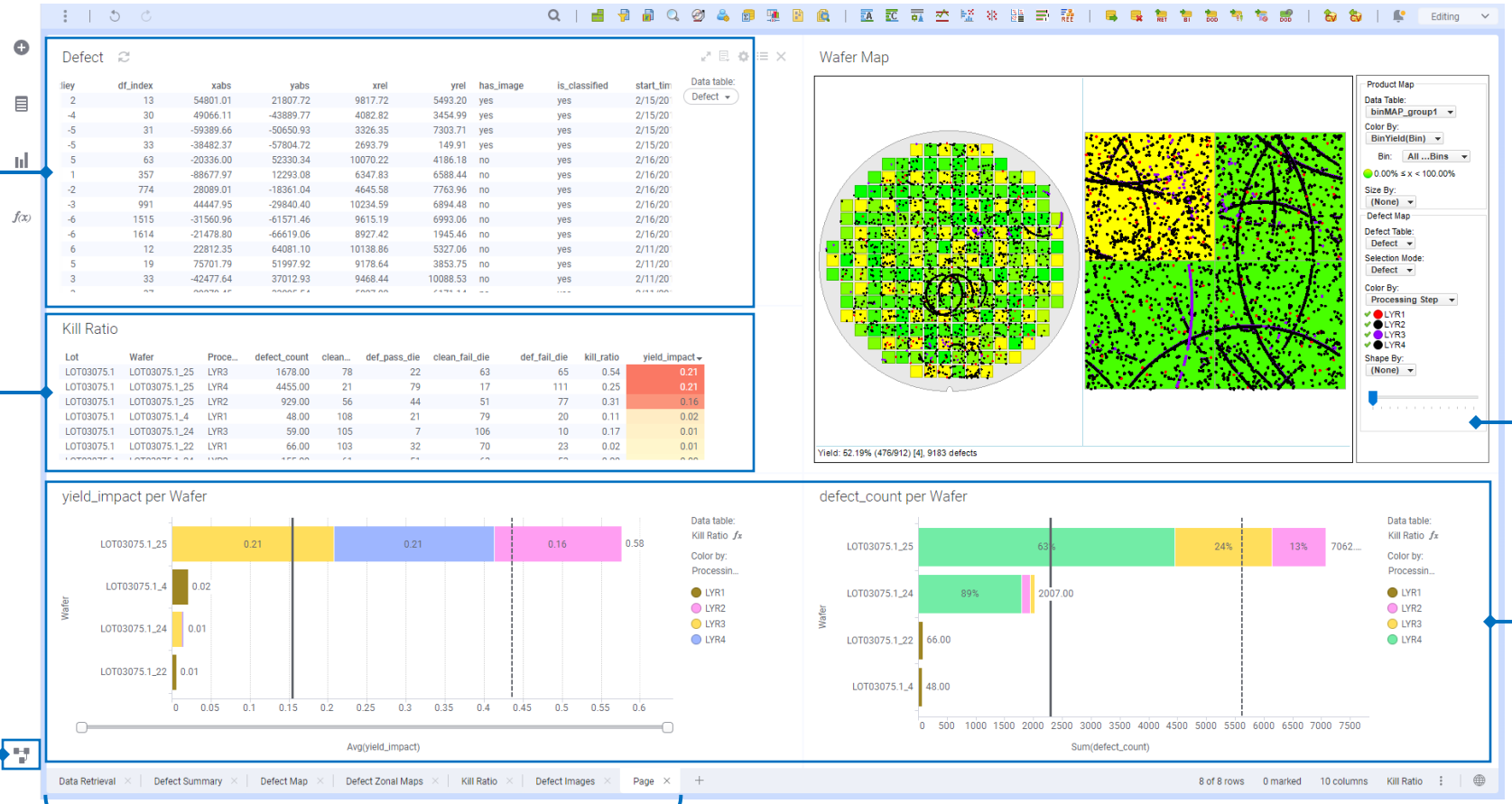


Defect | Binmap Overlays

Raw defect data

Defect summaries & statistics: CR, KR, YI, …

Intuitive data panel



Overlays: defects on pass/fail die binmap

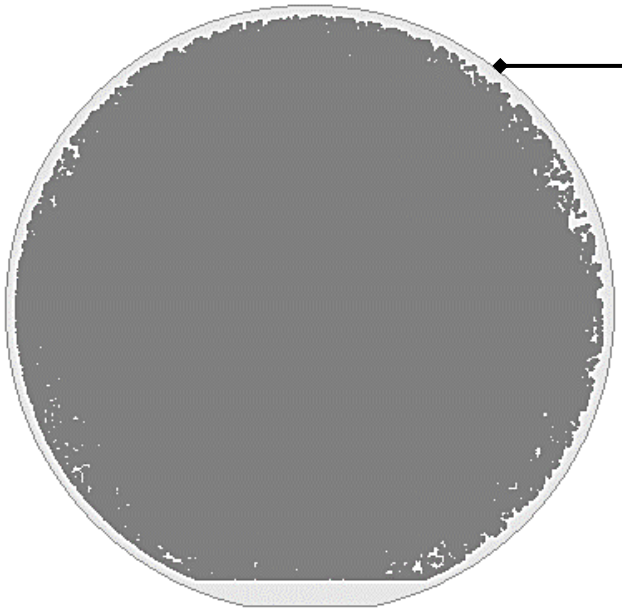
Stacking at lot, wafer, reticle, and die level

Defect drill-downs

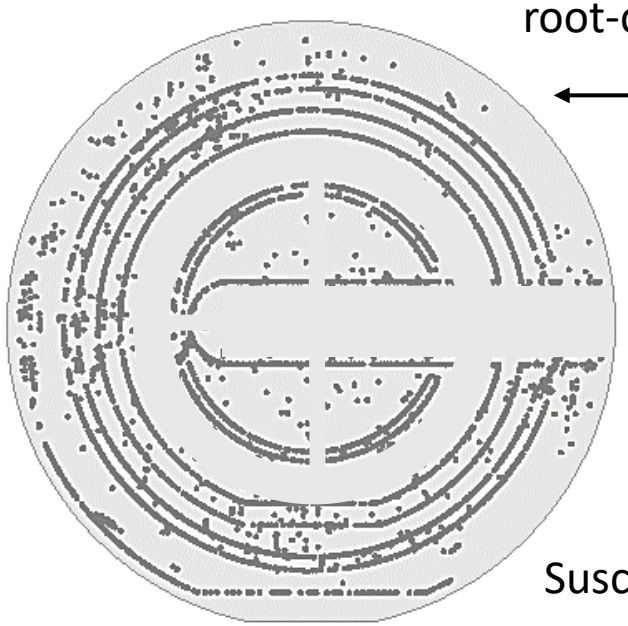
Many more pages with fully customizable visualizations and analysis types

Exensio™ Defect Management for SiC

Customer use case: identified root-cause of killer defects



Defect rebinning by size reveals root-cause for killer defects



Susceptor pattern emerges

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Summary

- **The next 5 years in SiC**
  - SiC CAGR outpaces semiconductors as a whole
  - Defectivity will remain high
  - Steeper challenges in transition to 200 mm wafers

- **Our solutions**
  - Exensio is the #1 platform for data analytics across semiconductor manufacturing
  - Continued adoption for SiC
  - Those with end-to-end deployments will grow faster

Product portfolio:

- Equipment connectivity
- Manufacturing analytics
- Process Control
- Test Operations
- Assembly Operations
- AI & ModelOps

Services:

- Data Integration
- Site, tools, data audit
- Building templates
- Classes and training

Thank You

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