Semilab Semiconductor
Physics Laboratory Co. Ltd.

www.semilab.com

Challenges and solutions in new generation SiC metrology

Eszter Najbauer – Application Scientist

4/18/24

Outline

About the Semilab group

Semilab solutions for the SiC process flow

Summary

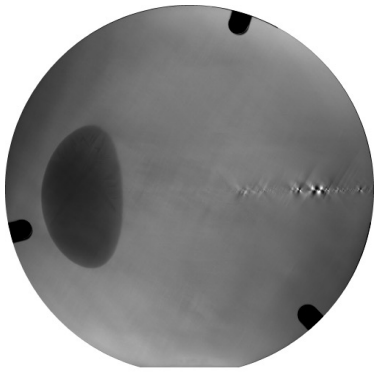

Boston
Tampa
Grenoble
Dresden
BUDAPEST
Seoul
Tokyo
Wuxi
Shanghai
Taipei
Singapore
No. of employees
1500+
Technologists & engineers
800+
Patents
400+
10 countries
15 sites
Since
1989
SEMILAB

SiC Power MOSFET Process Related Metrology

Substrate

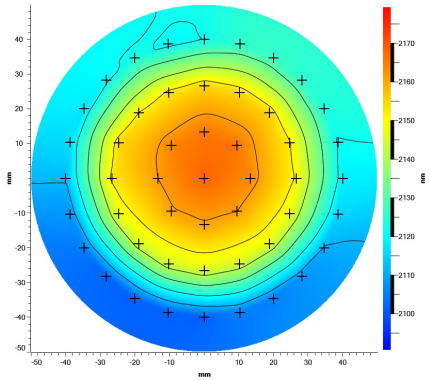
PSI-2200

Substrate defects



EIR-2201
EIR-2300

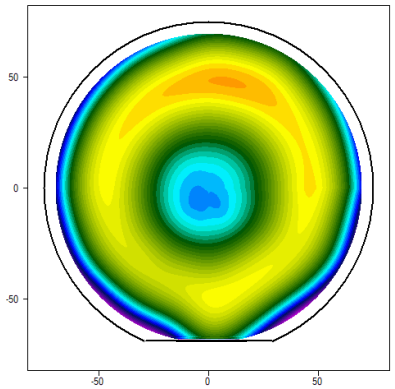
Epitaxial thickness



Epitaxial growth

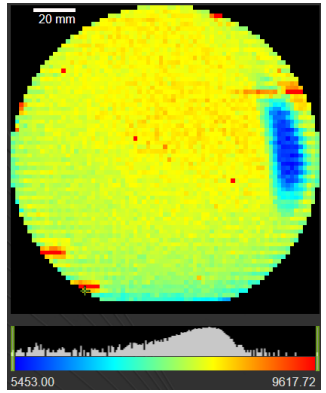
CnCV-230

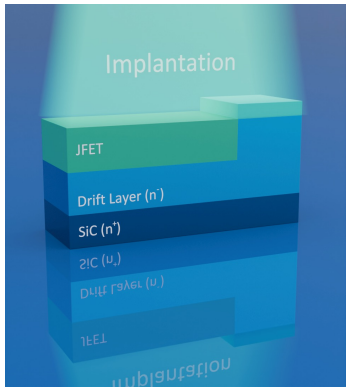
Doping profiles



SPL
LumiSiC

Defect inspection

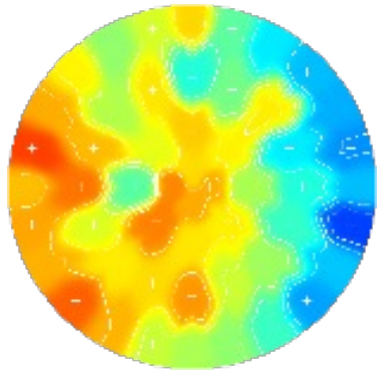




Selective ion implantations

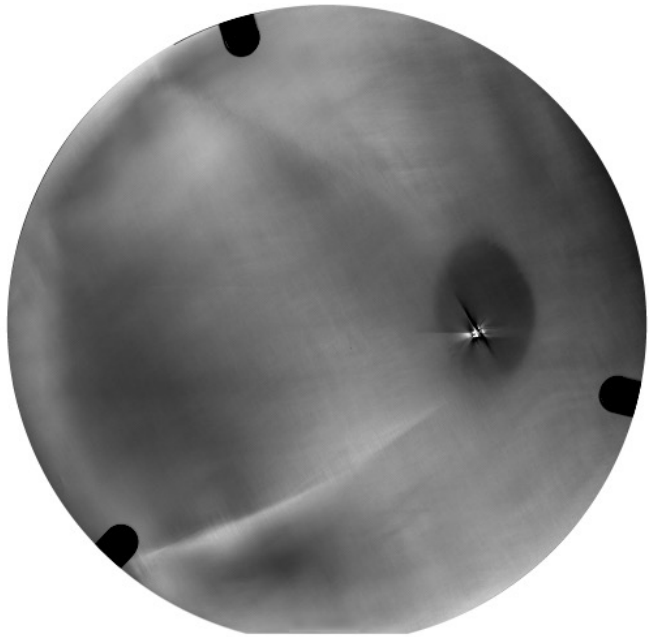
PMR-C

Implant Dose, Temperature



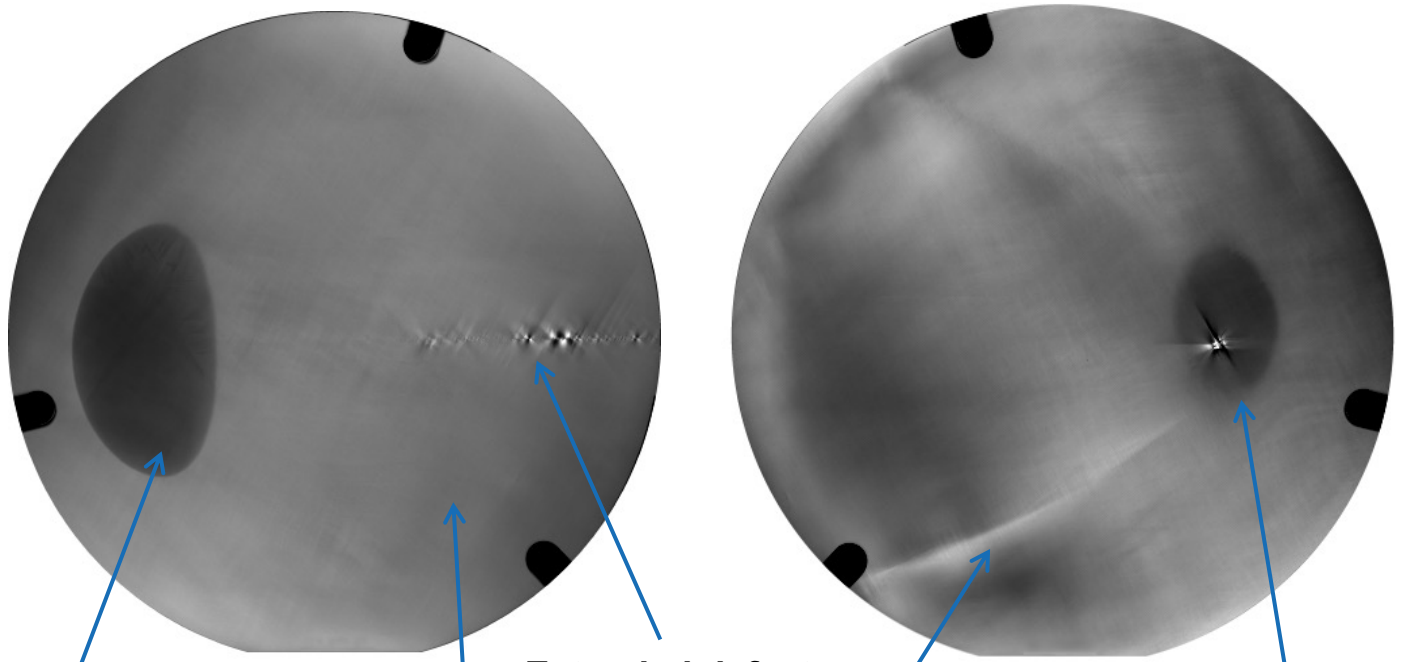
Substrate defect inspection

PSI-2200



PSI-2200: Stress field imaging

150 mm diameter **SiC substrate** wafers.



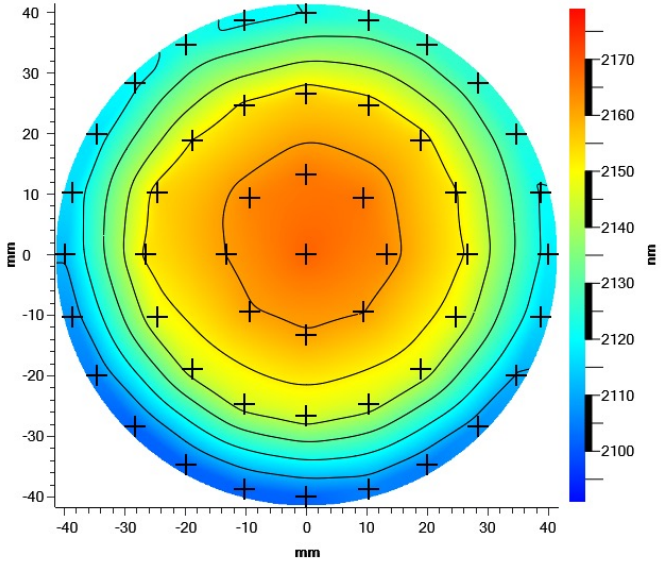
Crystal defect monitoring

Fully automated platform, with automatic loading for one selected sample size: 150 mm or 200 mm.

- Single load port, or optional dual load port.
- Low backside contact sample holder.
- Option: zero edge exclusion depending on configuration

Epi thickness measurement

EIR-2201, 2202, 2300



FTIR – EIR-2300

- **EIR-2300 for fully automated SiC fabs**
  - **Versatile loadport** configuration
    - 2 x SMIF or 2 x OC; OHT or AGV; manual
  - High-throughput dual-arm robot
  - **Compact footprint**, back-to-back or to-the-wall placement
- **EIR-2201, EIR-2202**
  - 2 x manual loadports or 1 x SMIF
  - EIR-2201: AGV option, EIR-2202: OHT, AGV options

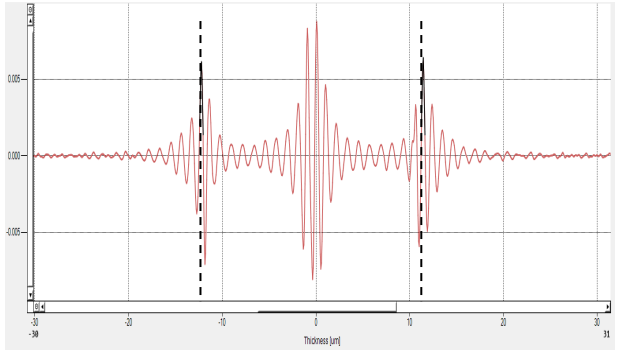
- **Gen2 metrology head** with improved lifetime
- Advanced SW features:
  - Wafer sorting capability
  - Tool status performance check report
  - Improved SiC interferogram analysis

- **Versatile applications:**
  - Thickness measurement: **Si epi, SiC epi**, SOI, SiGe…
  - **SiC buffer layer, Si transition zone, higher dopant concentrations**
  - Options for **dielectric composition**: BPSG, FSG, PSG
  - Option for **Oi, Cs**, H in SiN, and more

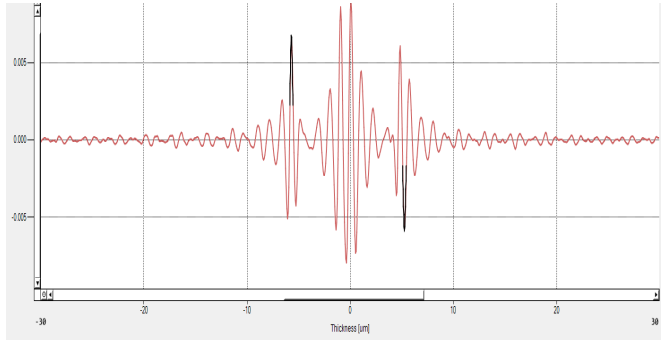
SiC epi thickness analysis methods

- **Interferogram**
  - Quickest
  - One layer only
  - Depends on structure

12 µm SiC epi

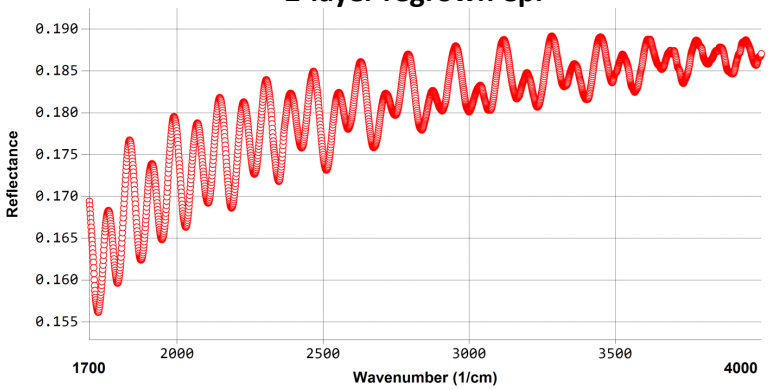


5 µm SiC epi

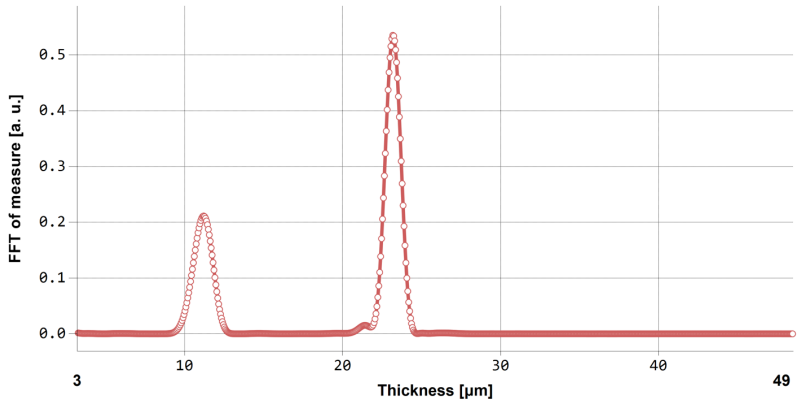


- **FFT analysis** of thickness oscillations in reflectance spectra
  - Potentially multiple (2) epi thickness (if all are > 2-3 um)

2-layer regrown epi



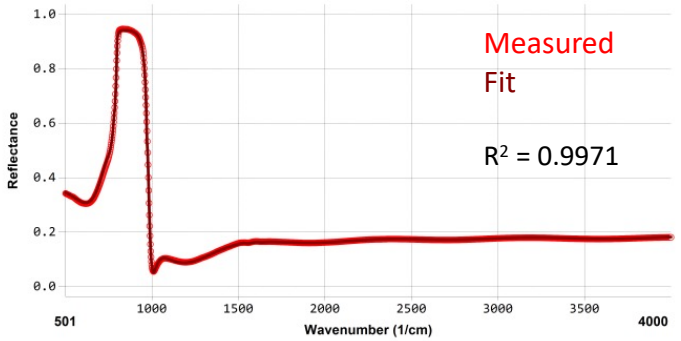
FFT

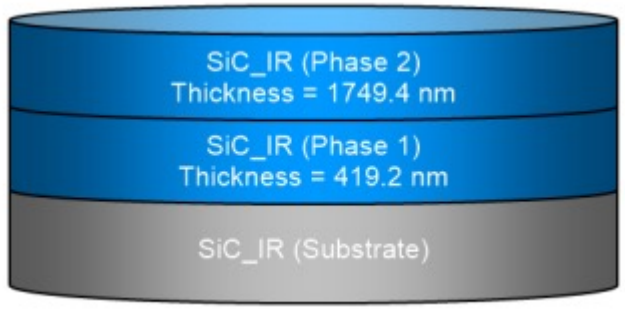


In collaboration with Fraunhofer IISB, Erlangen

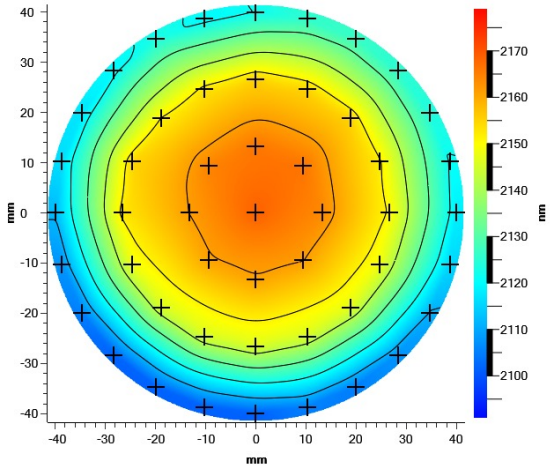
SiC epi thickness analysis methods

- **Optical modelling**
  - Depending on optical structure, thickness of multiple layers
  - Sufficient contrast between layers (> 5E17 at/cm^3)
  - Model sensitive to higher dopant concentrations (dopant concentration, resistivity maps)

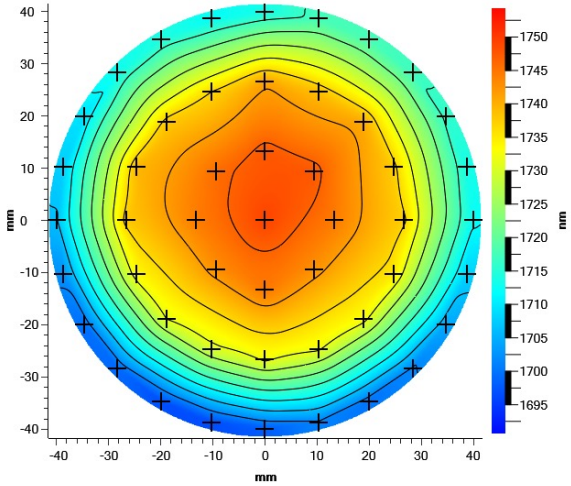




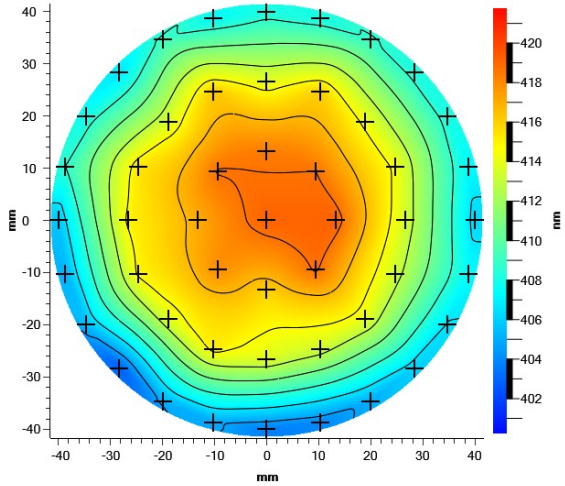
Total



Epi

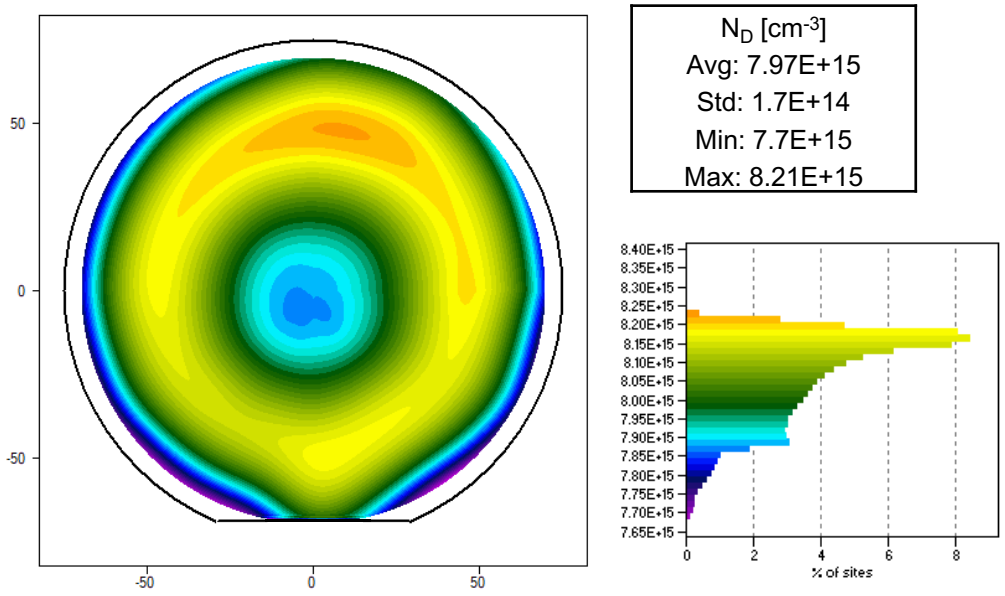


Buffer



CV &Doping profiles

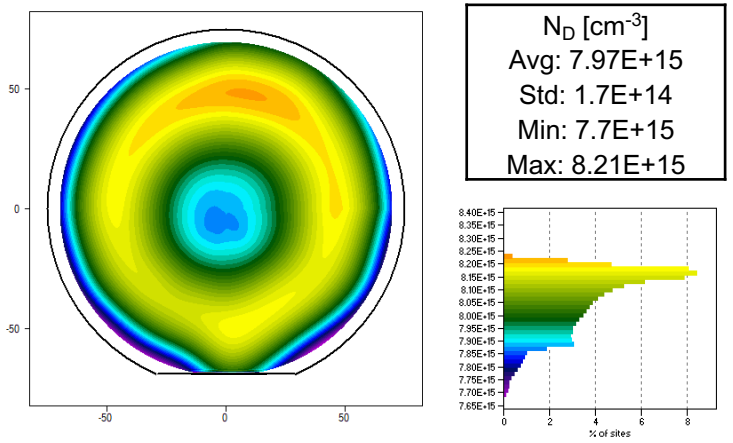
CnCV-230



N_D [cm^{-3}]
Avg: 7.97E+15
Std: 1.7E+14
Min: 7.7E+15
Max: 8.21E+15

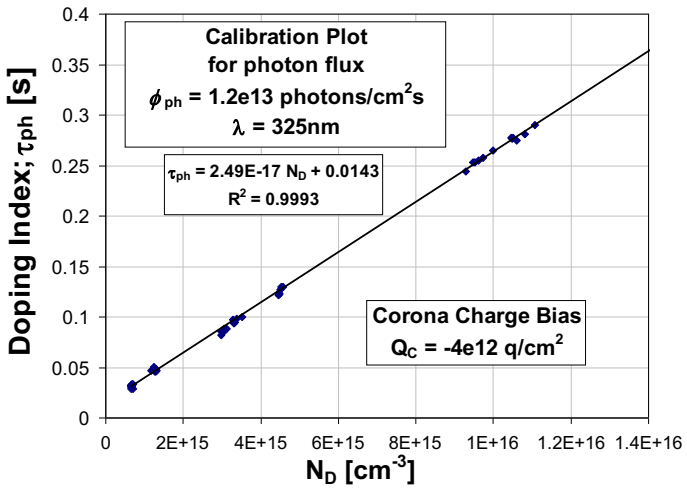
Corona non-contact CV - CV & Doping profiles

- Automated, production proven electrical metrology for **contactless, non-contaminating** measurements
- Integrated concurrent **pretreatment** for fresh epi SiC wafers
- Up to 200 mm
- 2023 development: **Kinetic Corona Voltage** time-resolved doping measurement mode
  - Based on charge photoneutralization time constant (τ_{ph})



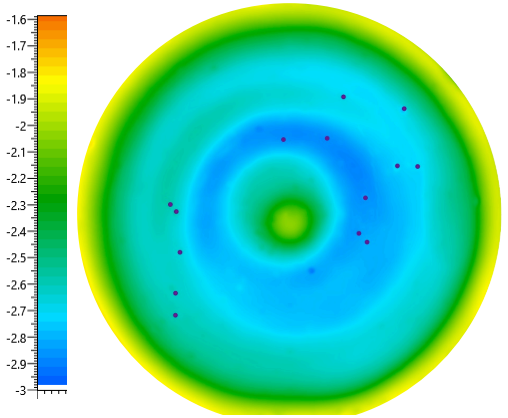
Applications:

- CV & Doping profiles
- QUAD defect detection full wafer mapping

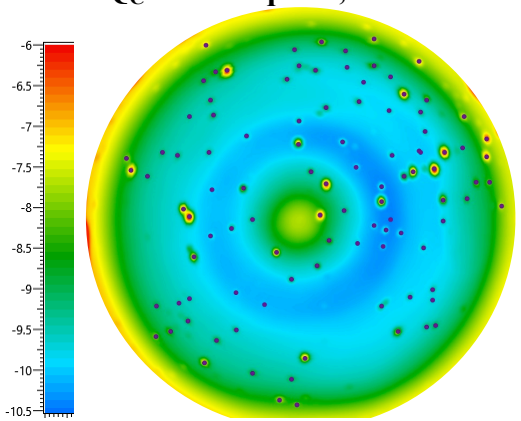


Corona non-contact CV - QUAD Defect Mapping

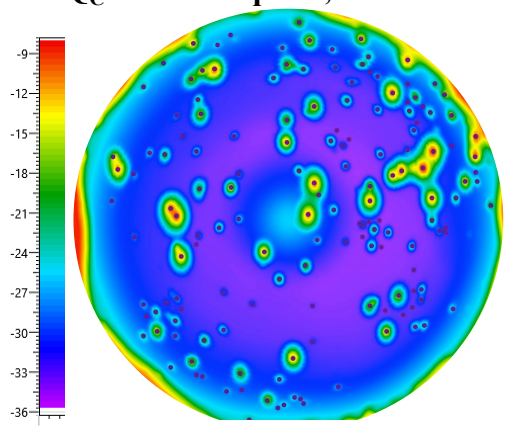
ΔQ_C = -4e11 q/cm²; 11 defects



ΔQ_C = -8e11 q/cm²;102 defects

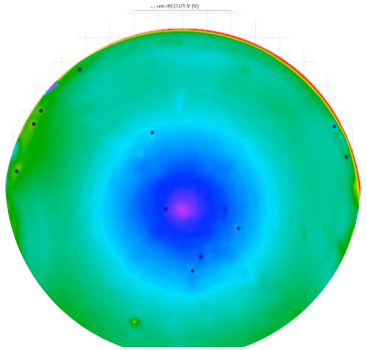


ΔQ_C = -1.6e12 q/cm²; 155 defects

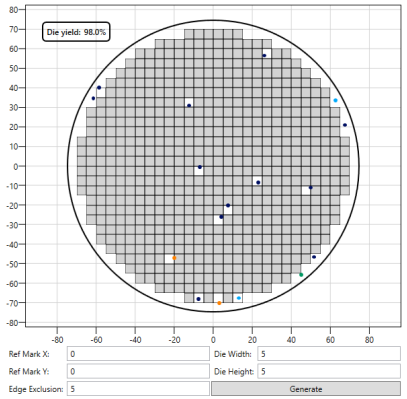


- Detection of **electrically active defects**
- With **increasing deposited corona charge, the defects become more visible** as sites with reduced depletion voltage.
- The electrical activity of these defects is quantified by the **QUAD defect contrast** (difference between depletion voltage at defect center and region outside the influence of the defect).

Example QUAD map



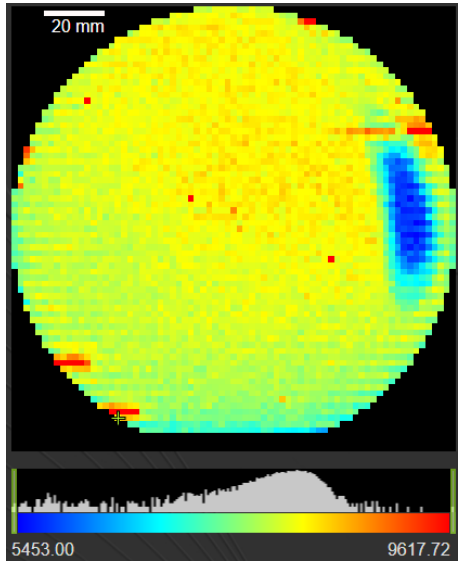
Die map with estimated die yield



Example QUAD map on an n-type SiC epi wafer (left) converted into a 5mm x 5mm die map with an **estimated 98% die yield** (right).

Epi and substrate defect inspection

LumiSiC & SPL

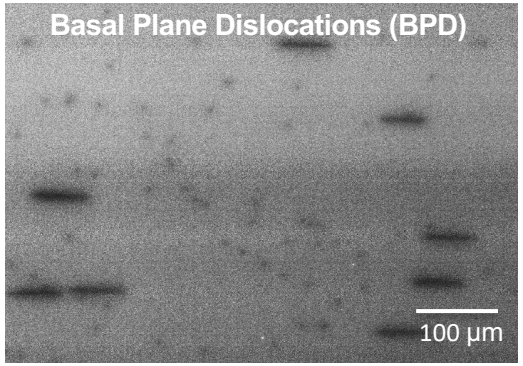


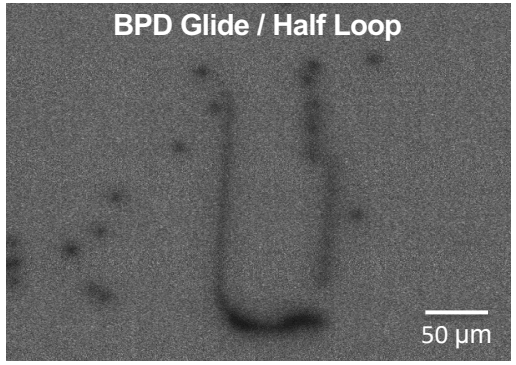
The upcoming **LumiSiC** system will integrate automatic **optical (AOI)** and **photoluminescence (PL)** measurement features for SiC defect inspection.

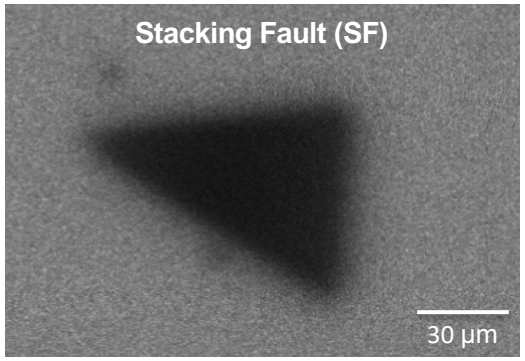
- AOI: measurement of **surface defects** for SiC epi and substrate (Micropipe, Triangle, Carrot, etc.)
- PL: measurement of **crystal defects** in SiC epi layers (BPDs, SFs, etc.)

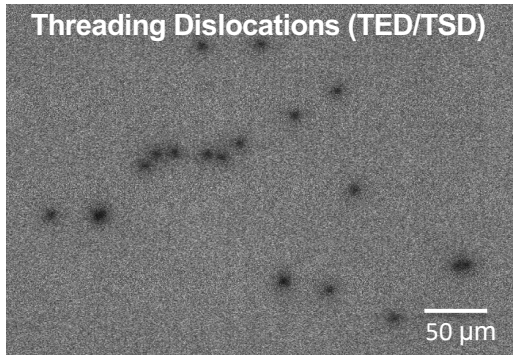
Features

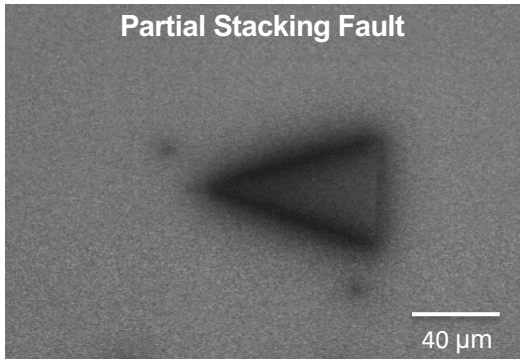
- Non-contact, non-destructive inspection technique
- High resolution full wafer imaging
- Simultaneous inspection of various surface and crystal defects
- Changeable optical filters for defect classification
- Automated multiband defect recognition and classification

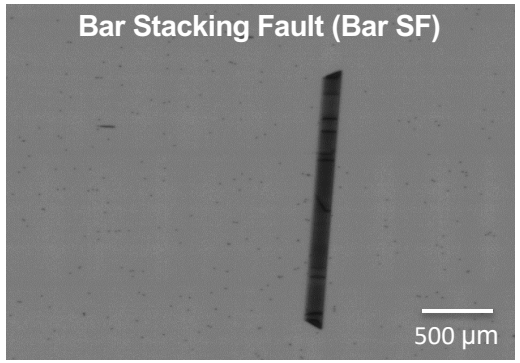






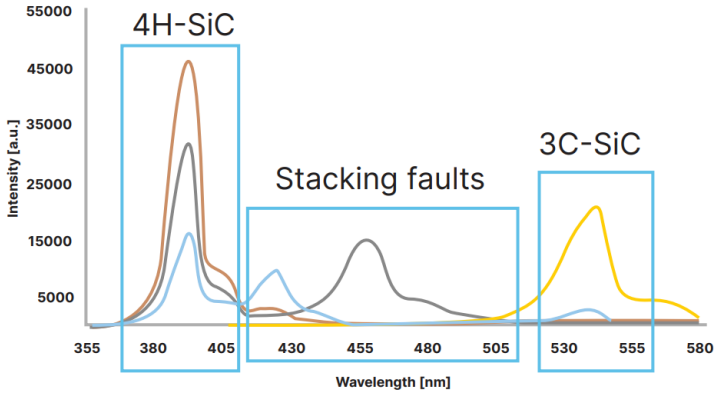


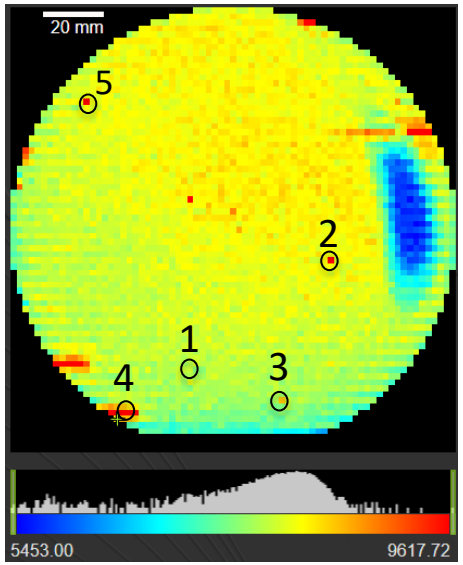


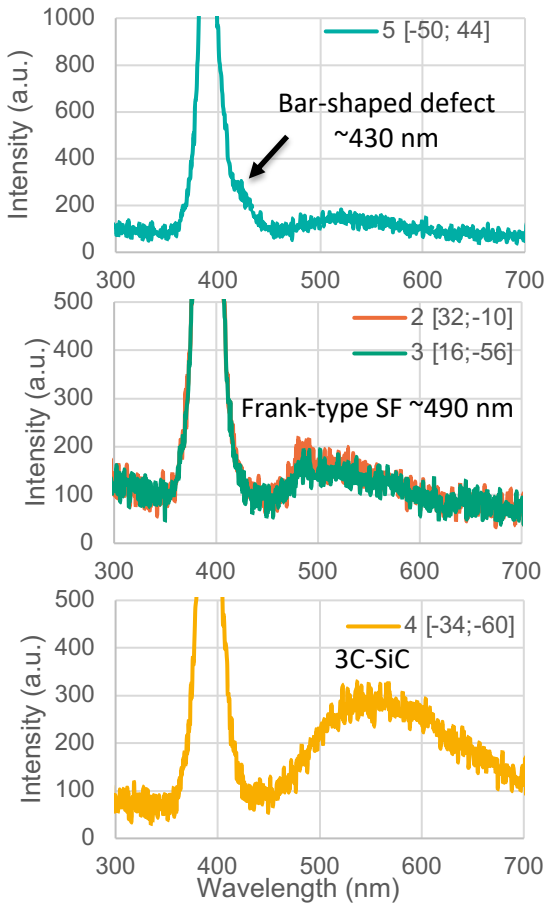


SiC Defect monitoring by spectral photoluminescence (SPL)

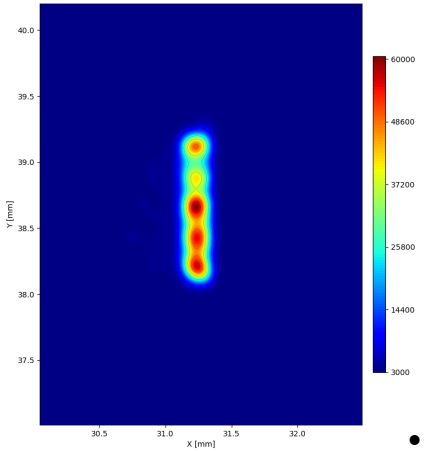
Non-visible defects: **stacking faults, dislocations**

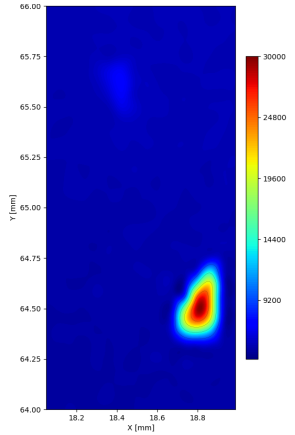






Microscanning at defect sites
25 µm spatial resolution





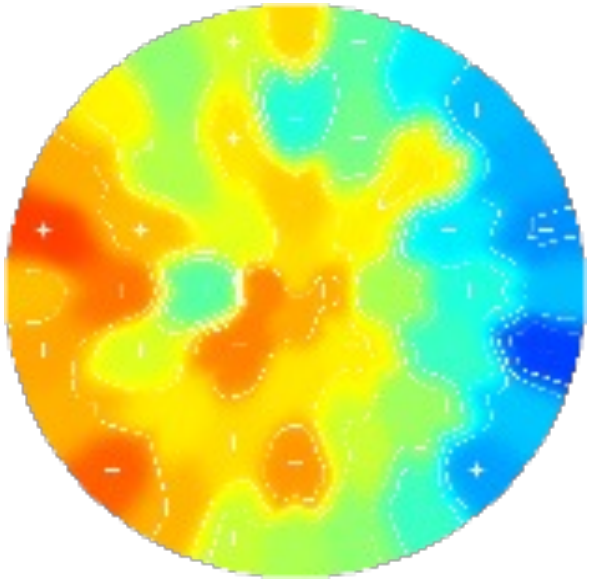
- Laser selection based on requirement: **266 nm, 355 nm, 405 nm, 532 nm, 638 nm, 975 nm** (up to five lasers)
- Laser spot size: 25-50 µm
- Spectrograph selection to cover UV to NIR (300 - 1650 nm). with a resolution of 0.2 - 2 nm
- **fully automated spectrograph calibration (spectrograph stability)**
- **fully automated laser power calibration (laser stability)**

Additional metrology options:

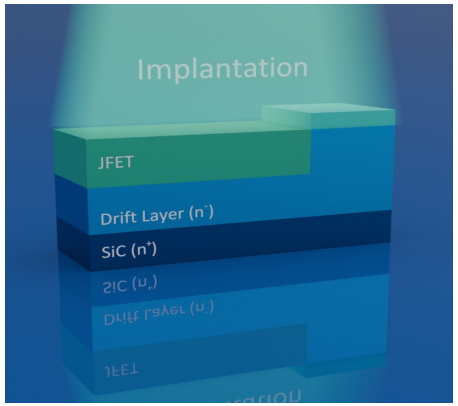
- Spectroscopic reflectometer (epi wafer thickness measurement) - **parallel with PL**
- Bow/warp

Ion implant monitoring

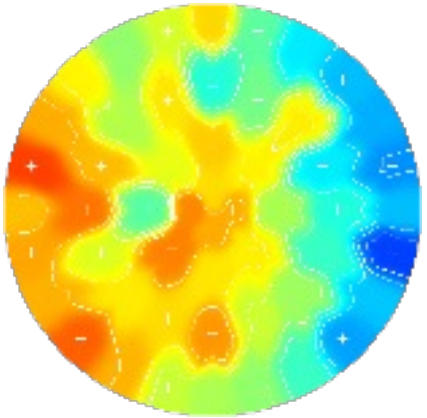
PMR-C



PMR-C - Ion implant monitoring



Pre-Anneal Ion Implant monitoring



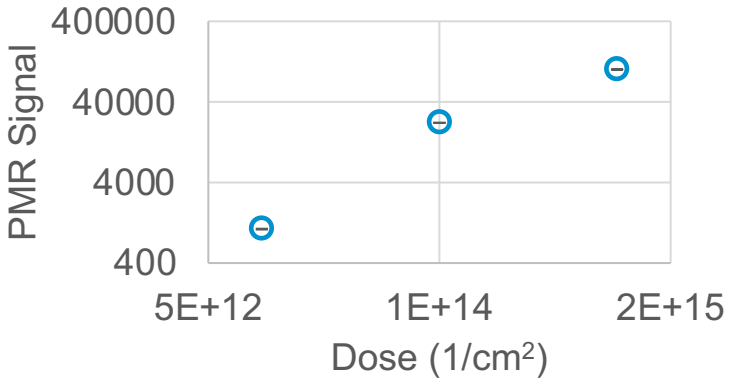
PMR-2300C

- **In-Line** measurement system
- **Pattern recognition**
- Monitoring of **product SiC and Si** wafers

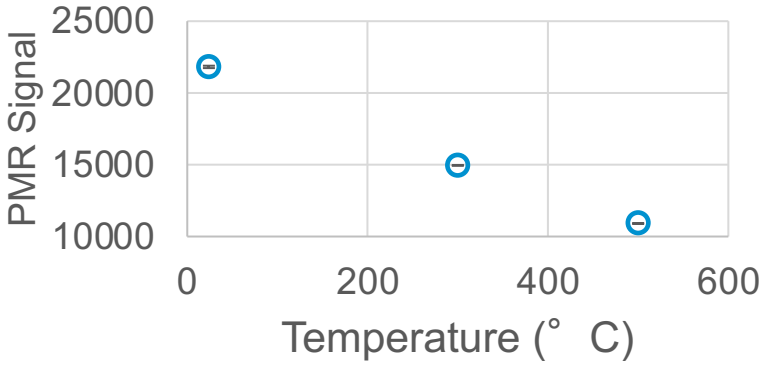
PMR-C key applications

- Dose monitoring
- Tilt angle
- Temperature

Al+, RT, Dose Ladder



Temperature, Al+, 300keV, 1e14



E. Najbauer, L. Balogh, J. Szívós, Sz. Biró, P. Basa, Z. Zolnai, A. Pongrácz: Comprehensive optical metrologies of implanted SiC wafer, poster at ICSCRM 2023

Semilab portfolio for SiC applications

EPI thickness measurement
EIR-2300

Dopant profiling
CnCV-230

Dopant profiling
MCV-2200

Trench characterization
MBIR-2200

Resistivity monitoring
RT-2201

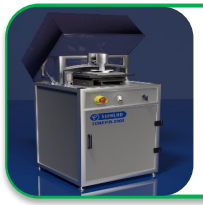
Resistance profiling
SRP-2100i

Stress field and defect detection
PSI-2200

Carrier lifetime monitoring
WT-2200

Impurity and defect detection
DLS-1100

Defect monitoring
SPL-2200



Resistivity monitoring (S.I.)
COREMA-2000

Surface and defect characterization
AFM-2100

Ion implantation monitoring
PMRC-2200

Wafer geometry
WG-2201

- Optical metrologies
- Non-destructive electrical metrologies
- Contact /destructive electrical metrologies
- Scanning probe microscopy

CS INTERNATIONAL CONFERENCE
ANGELTECH

Thank you for your attention!


Power


Optoelectronics

RF