CS INTERNATIONAL CONFERENCE 2023

Bruker X-ray Solutions for GaN Power Device Metrology

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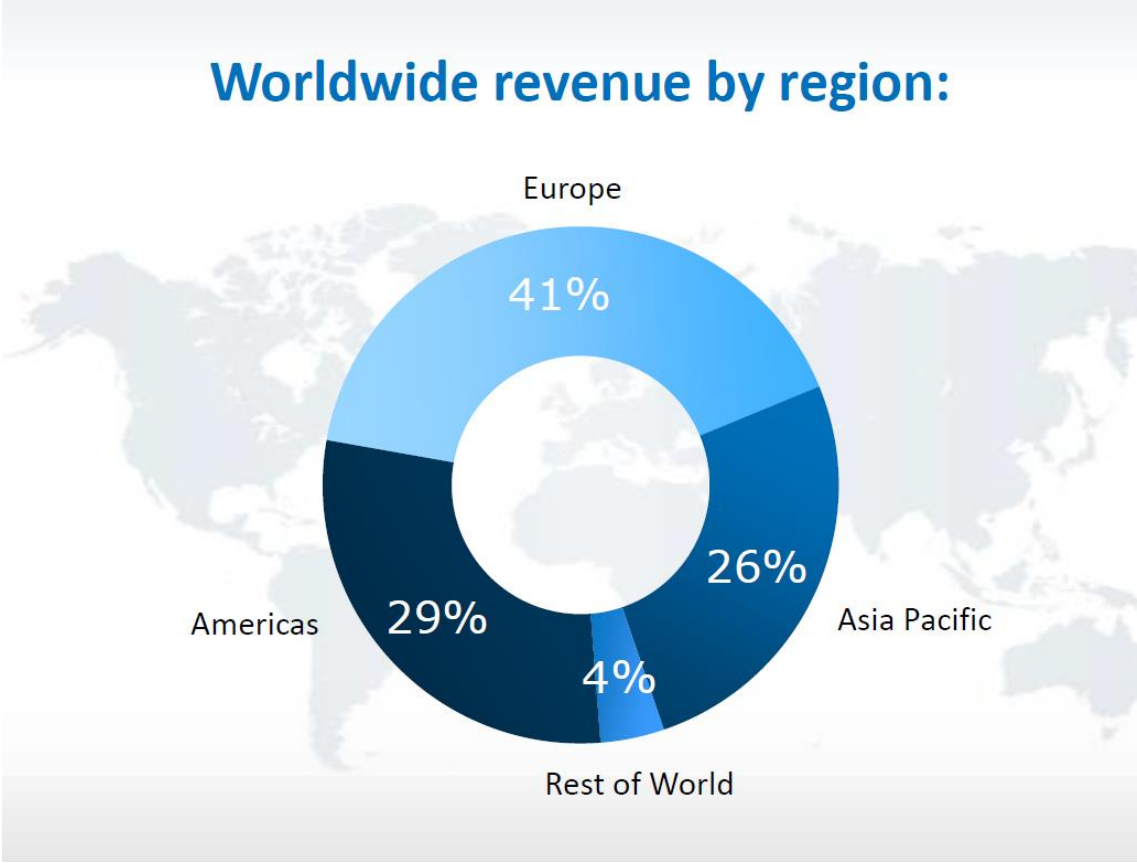
Dr. John Mallows

Contents

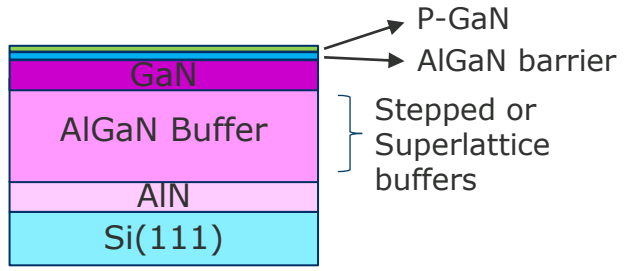
Bruker Overview

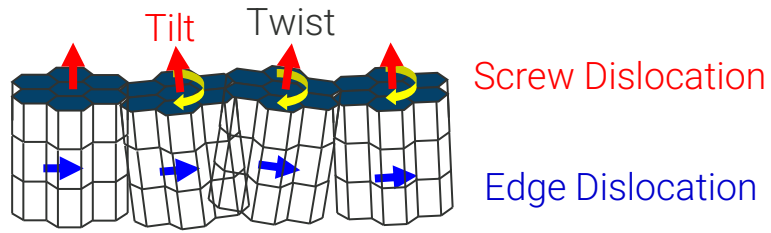
- Leaders in the markets we serve
- Innovation driven culture:
  - 9% investment across the company
  - 18% R&D investment for Bruker Semi products
- Over 6,000 employees worldwide
- Stable and profitable growth:
  - Founded more than 55 years ago
  - Publicly traded NASDAQ; BRKR

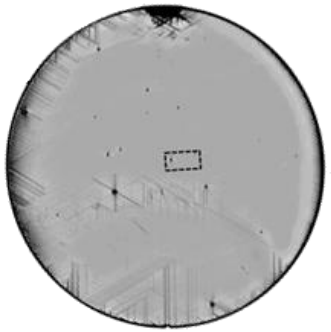


Importance of X-ray metrology and defect inspection for GaN power devices

- Device thickness and composition are critical to electrical properties but are difficult to measure
- GaN and AlN layer quality are critical
  - Monitor the crystal quality by measuring FWHM of rocking curves
- Defectivity during growth can affect the wafer quality
  - Cracks, slips, strain, and dislocations
- Bruker solutions: non-destructive X-ray metrology can monitor epi and substrate quality, improve process reliability and yield





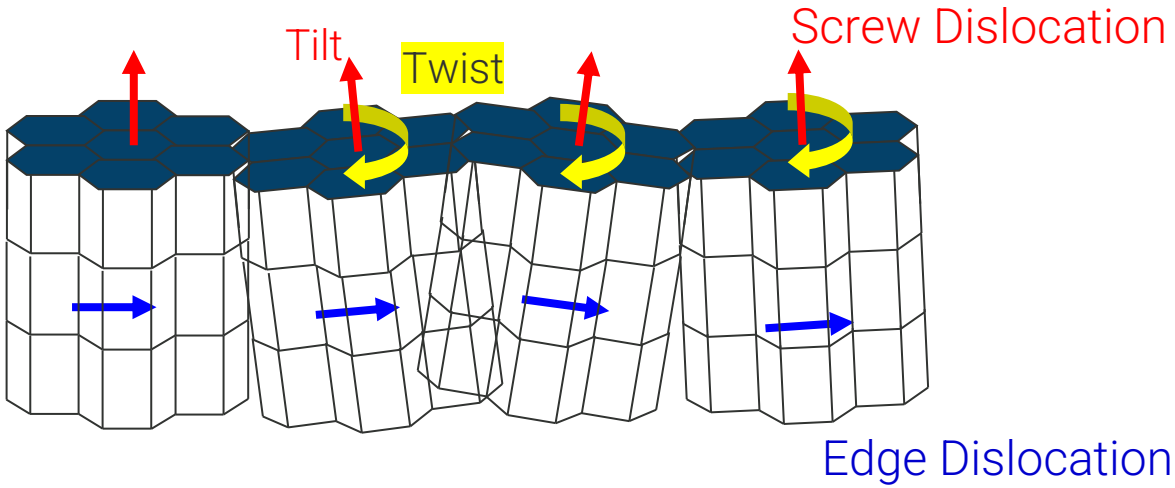


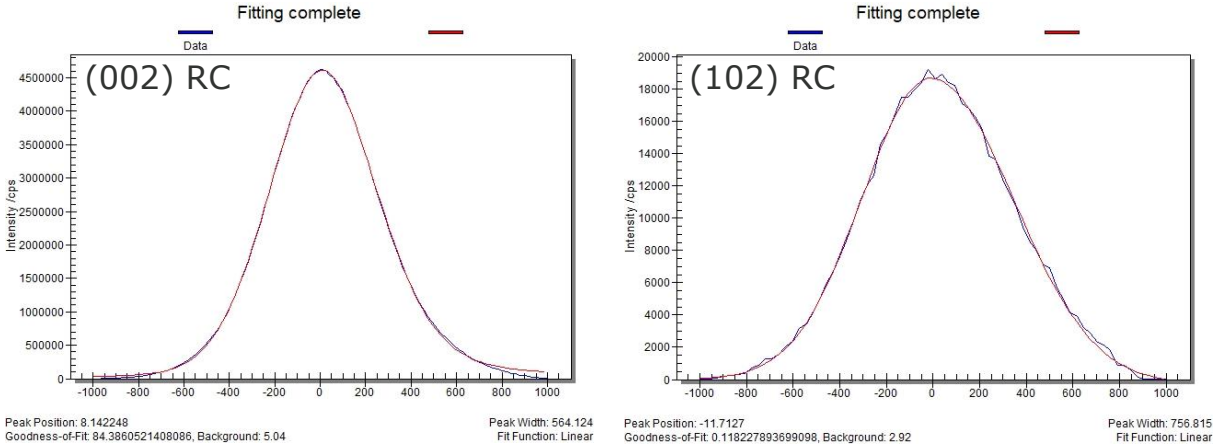
Defectivity

GaN BKM Story

Rocking Curves

- GaN grows in “mosaic” structure
  - Tilted with respect to surface
  - Twisted (rotated) with respect to each other
  - Range of tilt and twist is important for device as it sets dislocation amounts
- The tilt and twist of a particular layer can be measured using rocking curves:
  - The tilt is calculated using the (002) reflection
  - The twist (100)/(110) is calculated from (002) and (102) rocking curves[1]

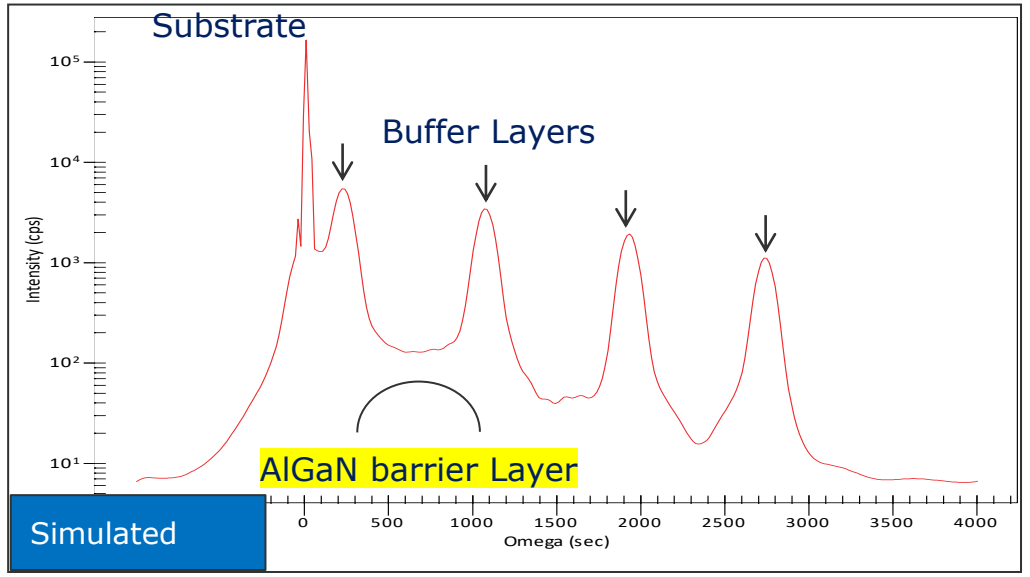




[1] Srikant V., Speck J. S., Clarke D. R., *J. Appl. Phys.* 82 **9** 4286-4295 **1997**

Hidden AlGaN Layer

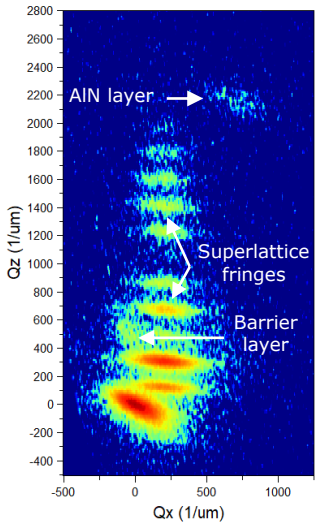
- AlGaN is a widely used material in the production of power transistors and other semiconductor devices
- Controlling the Al composition of the barrier is critical for strain engineering
  - The AlGaN barrier can be buried under the buffer layer peaks
- Bruker has developed techniques for eliminating the buffer layer problem for thickness and composition



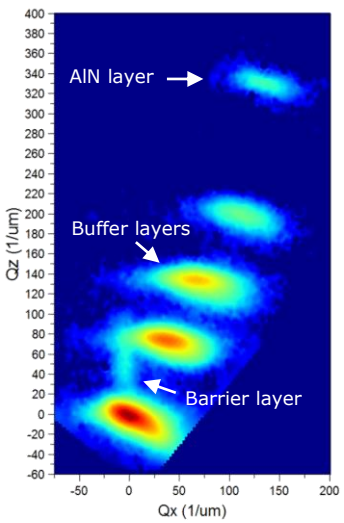
Bruker Solutions for Hidden AlGaN Barrier Layer

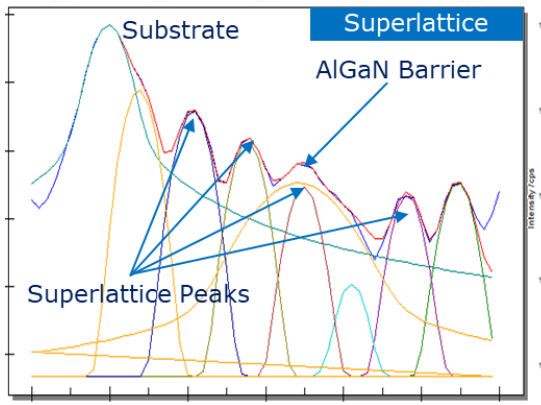
- Bruker solutions - HRXRD
  - Asymmetric RSM: can determine the composition and relaxation of barrier layer and buffer layers
  - Composition scan: a line scan across GaN layer of reciprocal space in the L direction, allowing direct measurement of AlGaN barrier layer with minimal interference from the buffer layer
    - High throughput and repeatability
    - Bruker proprietary scan and analysis

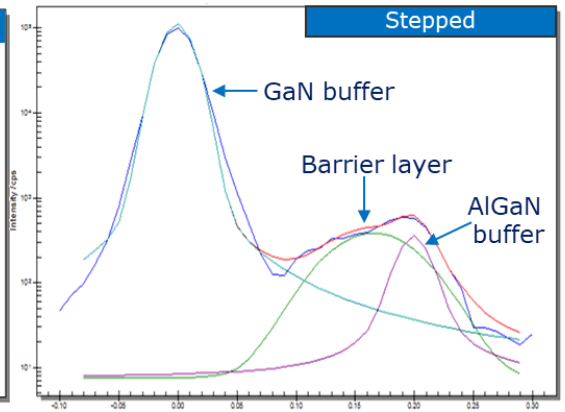
SL buffer



Stepped buffer

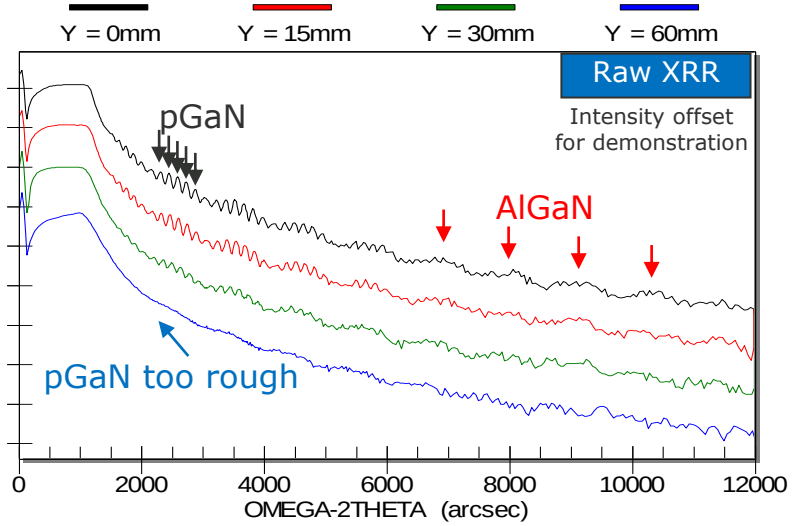


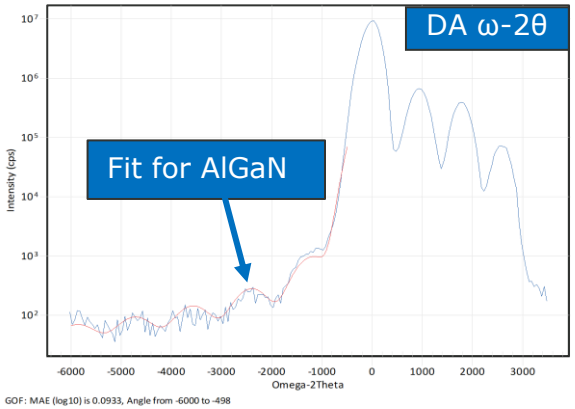


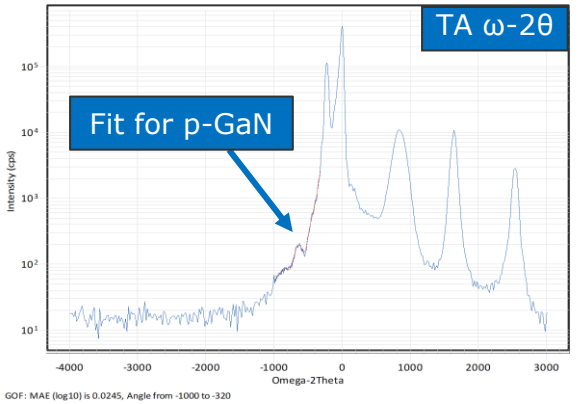


Thick pGaN Problem

- Device cap and barrier layer thickness are important for AlGaN/GaN HEMTs
- Measuring thick pGaN is difficult with all metrology techniques
  - Fringes disappear quickly when layer is too rough
  - AlGaN fringes can also lose intensity due to sample roughness
- Bruker solutions:
  - Bruker XRR can measure the thickness of AlGaN barrier and pGaN layer
  - Bruker HRXRD technique can also measure the thickness of AlGaN barrier and pGaN layer

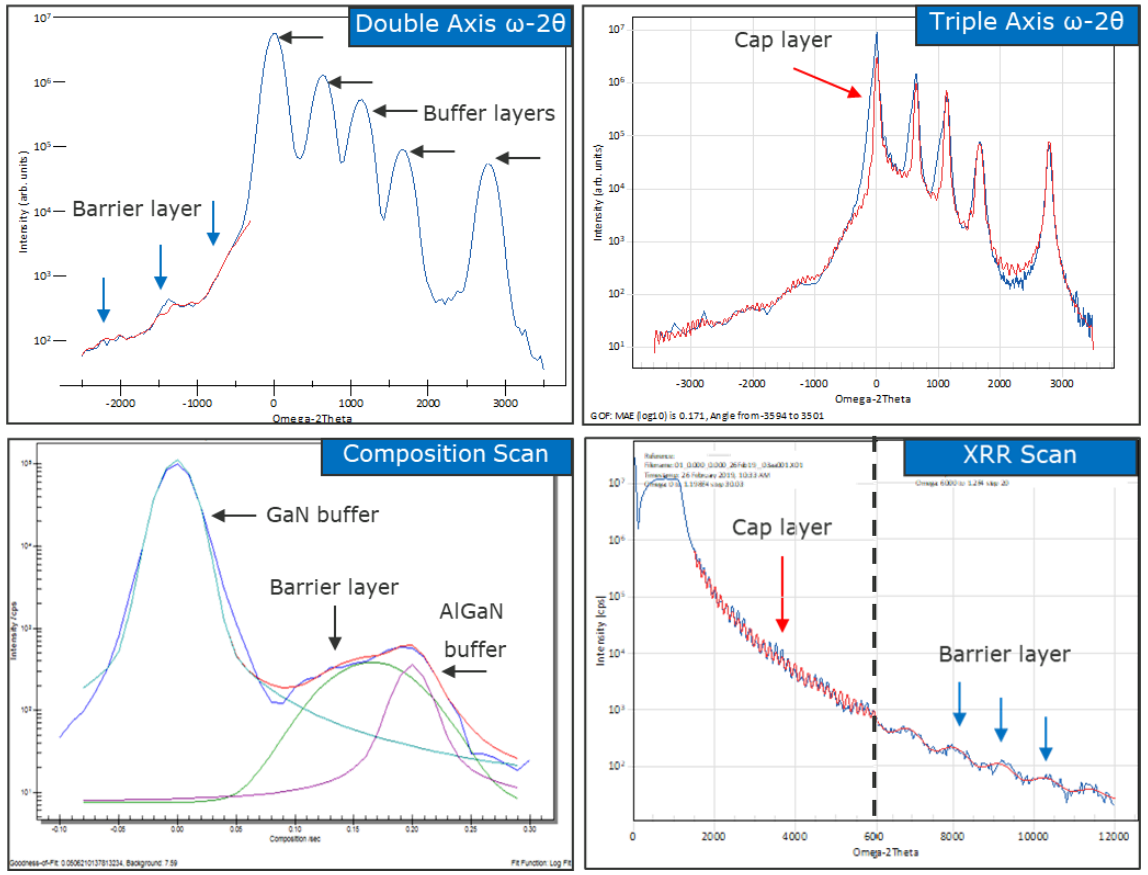






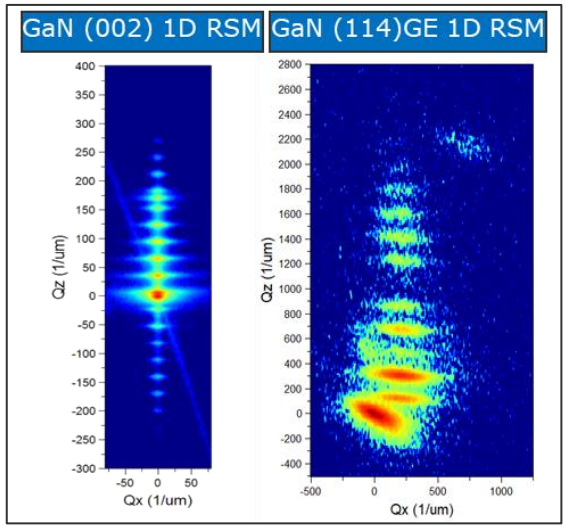
GaN on Si Metrology BKM Overview – Stepped Buffer

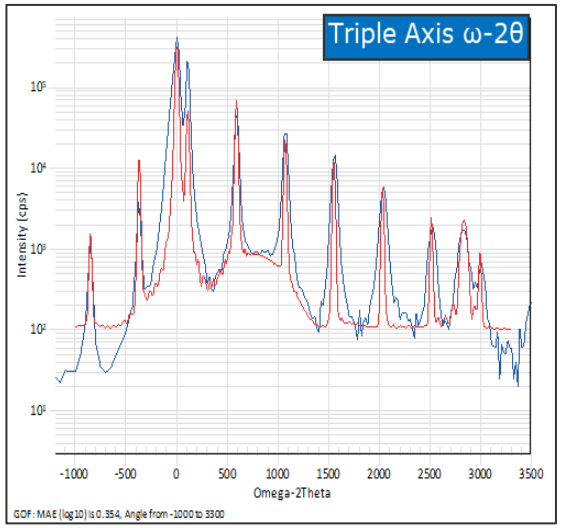
- Device layer thickness and buffer composition:
  - pGaN fringes measured in triple axis scan
  - AlGaN barrier fringes measured in double axis scan
- Barrier and buffer layer composition / relaxation:
  - Reciprocal space maps
- Barrier and cap layer thickness:
  - XRR (two-stage fitting)
- Barrier layer composition:
  - Bruker proprietary composition scan
- Crystal quality:
  - GaN (002) + (102) rocking curves

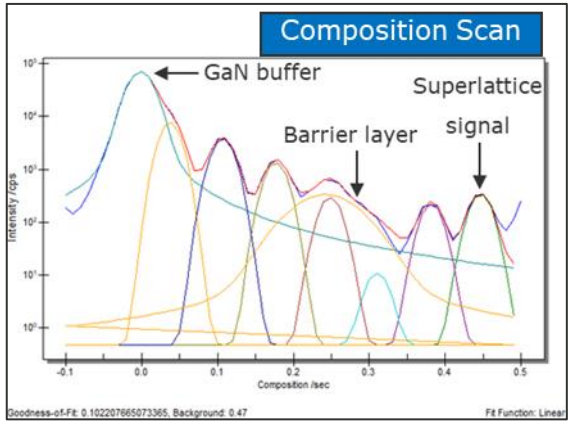


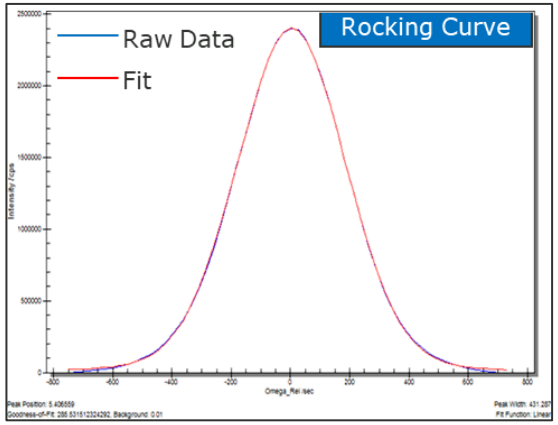
Bruker BKM - GaN on Si Metrology – SL Buffer Structures

- Buffer layer and superlattice composition, superlattice pair thickness:
  - Triple axis Omega-2Theta scan
- Barrier and buffer layer composition / relaxation:
  - Reciprocal space maps
- Barrier and cap layer thickness:
  - XRR
- Barrier layer composition:
  - Bruker proprietary composition scan
- Crystal quality:
  - GaN (002) (102) rocking curves





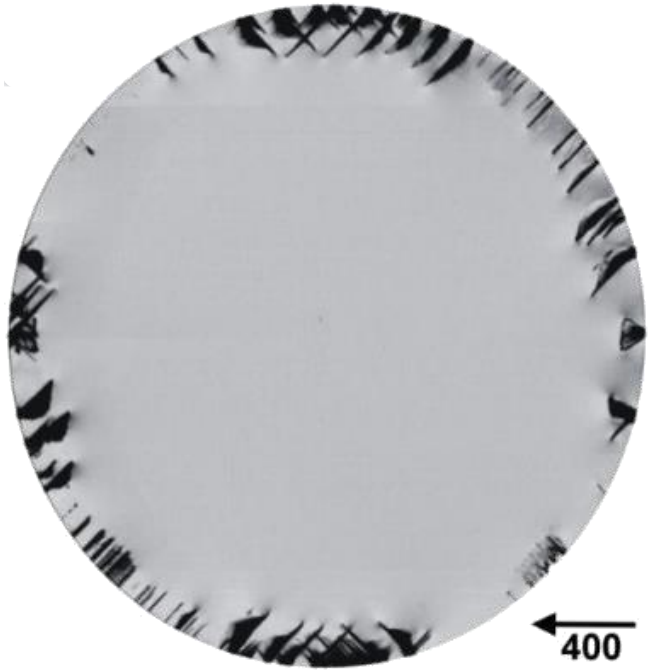




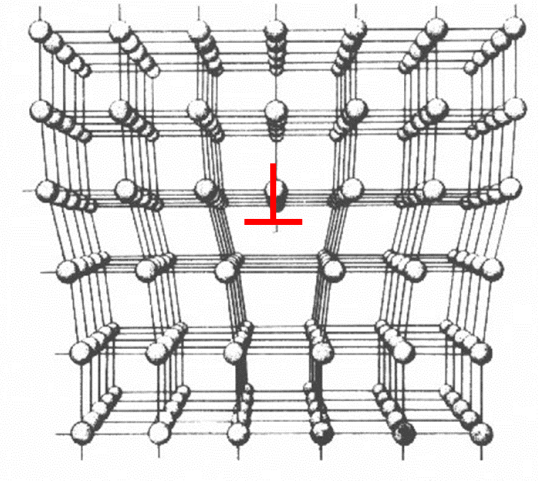
XRDI solutions

X-ray Diffraction Imaging (XRDI) or X-ray topography

- Crystalline defects induce changes to the spacing (strain) and/or the rotation (tilt) of the crystal lattice around them forming a strain field
- XRDI is a non destructive technique that allows imaging of the strain field induced by these defects
  - Strain fields are always much larger than the defects themselves
- XRDI is sensitive to
  - Edge cracks and layer cracks
  - Dislocations
  - Slip
  - Inclusions
  - Other crystalline defects



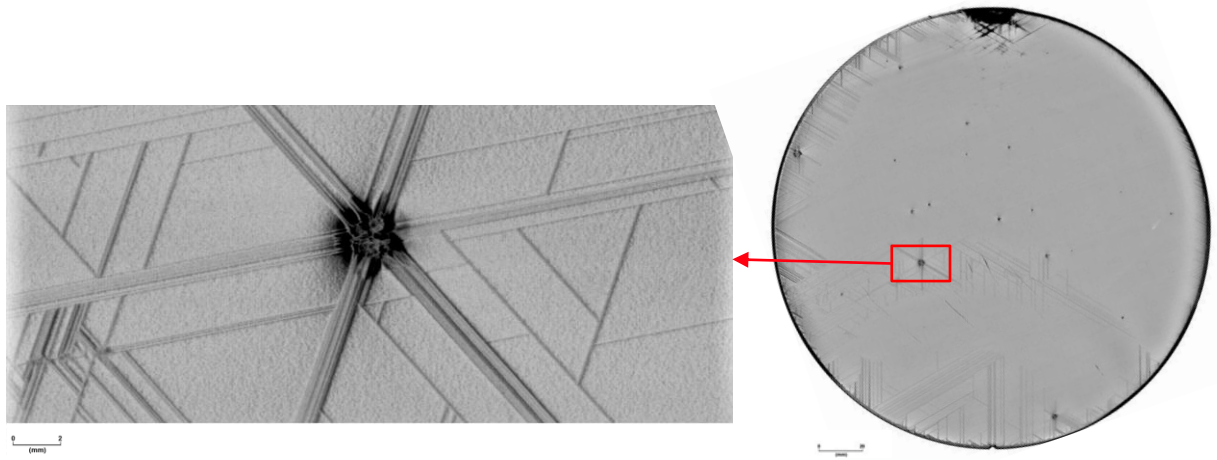
Prime (001) Silicon wafer after plateau anneal T>800°C for several tens of seconds



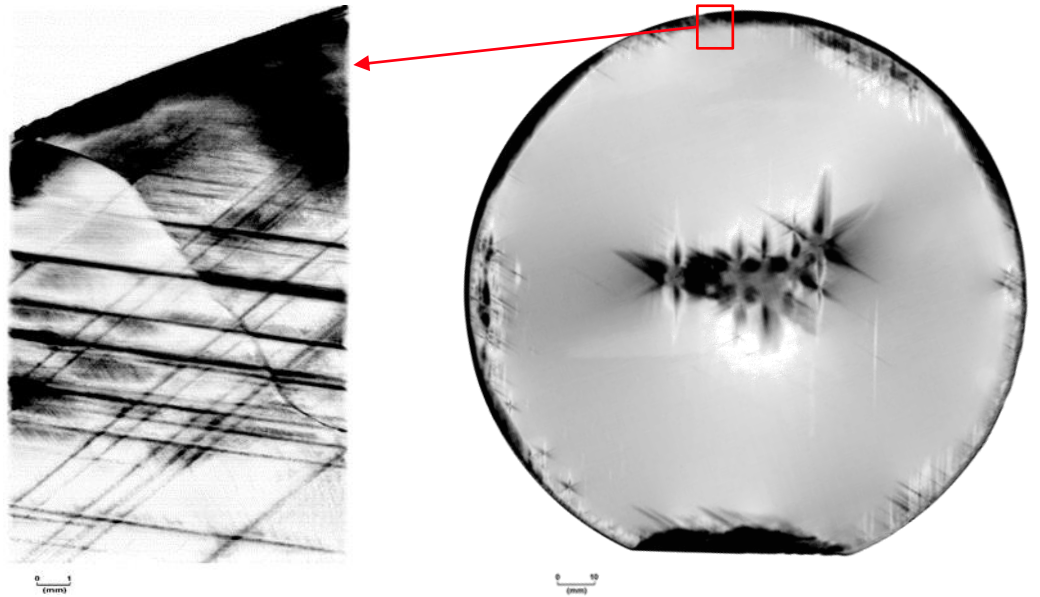
Example of a dislocation and the deformation of the crystal lattice

Bruker XRDI Solutions for GaN on Si

- High resolution review scan can be used to investigate nature of defect
  - Defect cluster near the wafer centre at the intersection of hexagonally aligned linear defects

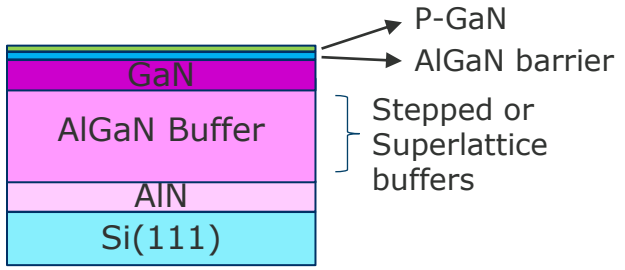


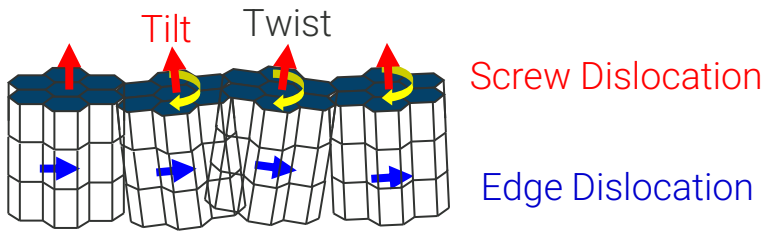
- XRDI technique can see defects extending through full substrate thickness with cross-section scans
  - Dislocations, slip and cracks
  - Strain and edge effects
  - Blanket or patterned wafer

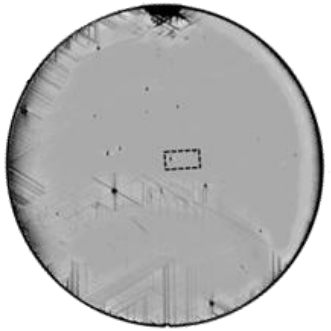


X-ray metrology for GaN power summary

- Bruker solutions: non-destructive X-ray metrology can monitor epi and substrate quality, improve process reliability and yield.
  - GaN (002) + (102) rocking curves used to measure the tilt and twist of epilayer
  - Bruker proprietary composition scan
  - RSM for relaxation and composition of barrier and buffer layers
  - XRR used to model thickness of pGaN and AlGaN barrier layer
  - HRXRD used for buffer layer and superlattice composition, superlattice pair thickness, pGaN and barrier thickness
  - XRDI used to image full wafer for defects, HR and cross-section scans used to further investigate nature of defects





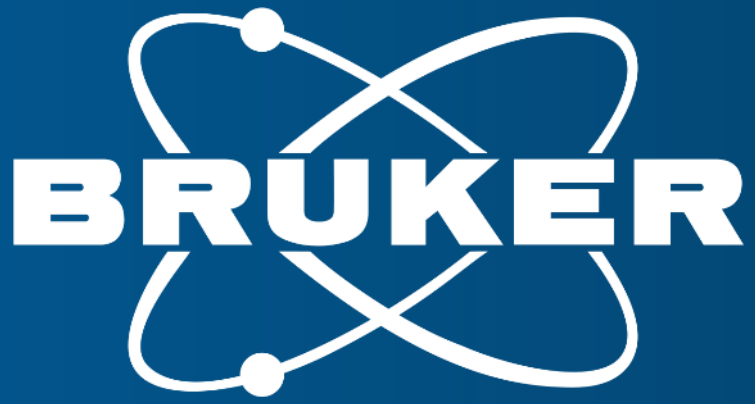


Defectivity

Product Overview

Bruker Products

- Production-dedicated systems for analysis of compound semiconductor materials
- High throughput and repeatability
- Full automation, ease-of-use software



Innovation with Integrity