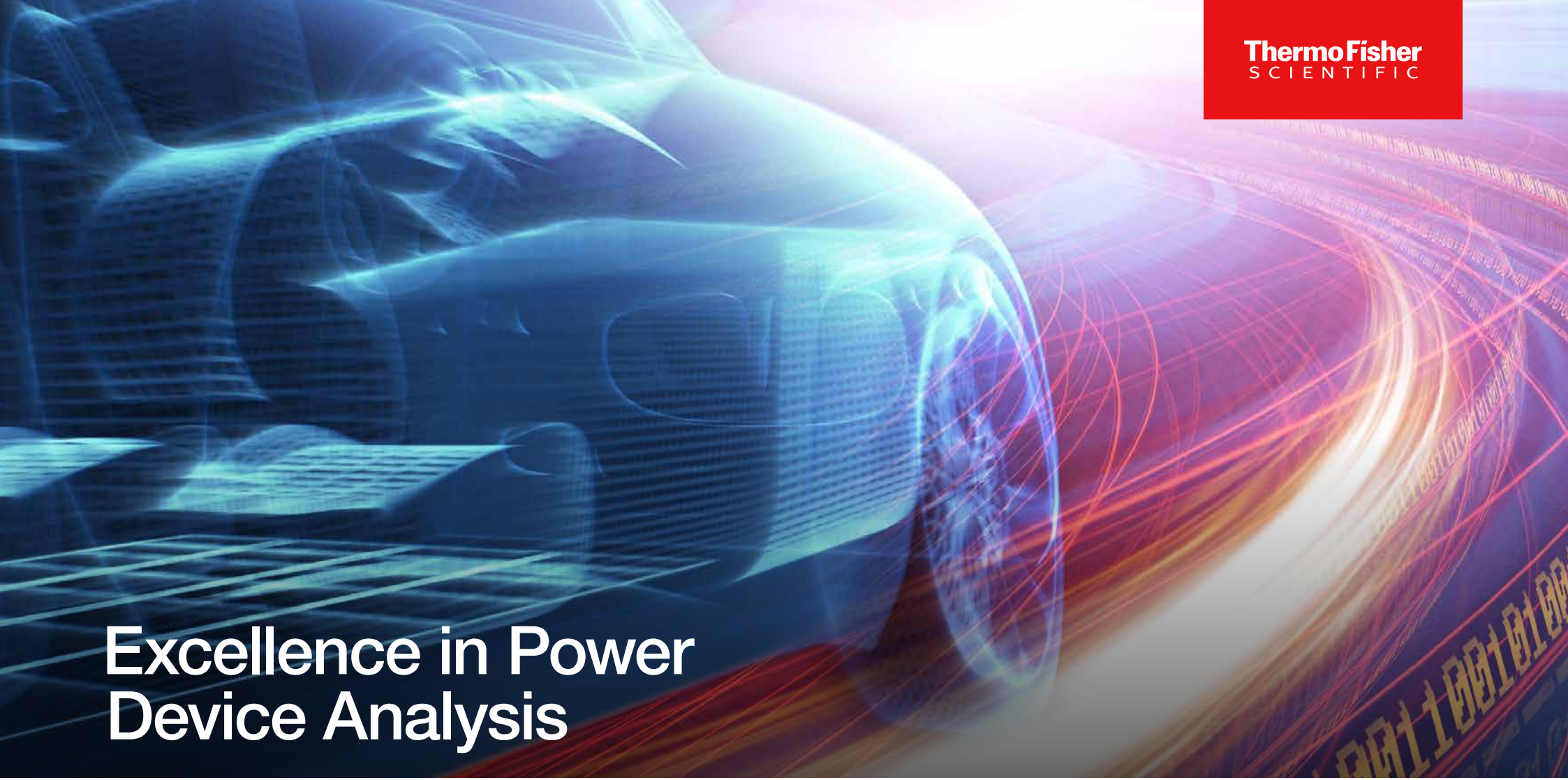


ThermoFisher SCIENTIFIC

Excellence in Power Device Analysis

Techniques and workflows to energize failure analysis for compound semiconductors

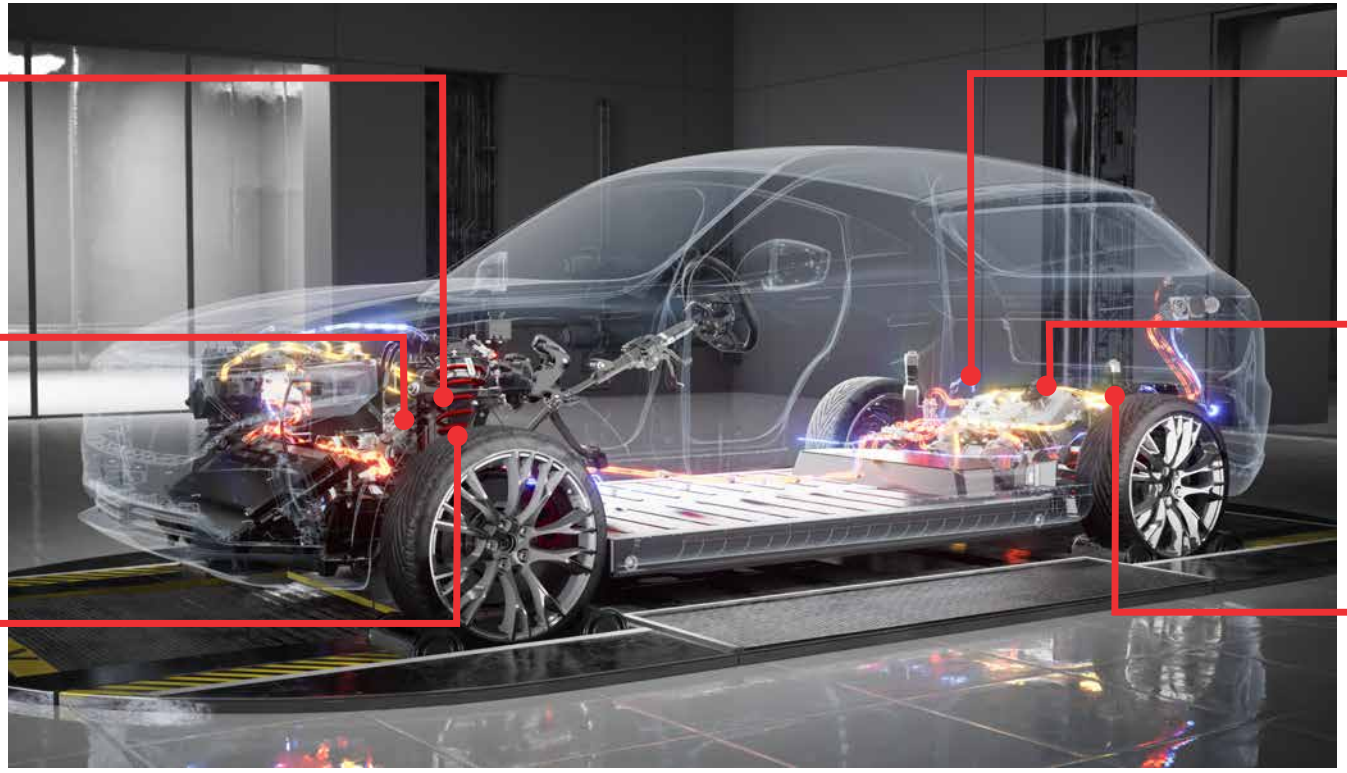
thermo scientific

Challenges

Power electronics are undergoing an exciting transformation with wide-bandgap (WBG) semiconductors, such as silicon carbide (SiC) and gallium nitride (GaN), permitting devices to operate at much higher voltages, frequencies, and temperatures than conventional semiconductor materials. Unfortunately, WBG semiconductors can be hard to manufacture, and defects can be difficult to pinpoint and analyze. Potential failures may be caused by crystalline defects in substrates or by electrical leakage issues between the drain and source (IDSS) and/or between the gate and source (IGSS).

Solutions

Overcoming these challenges requires fast acquisition of accurate failure analysis data and lets you locate Angstrom-size defects without damaging sensitive circuits. Effective solutions also need to let you prepare high-quality samples and accurately characterize critical dimensions, to discover the root cause and resolve critical defects with confidence. To meet these needs, Thermo Fisher Scientific has developed high-productivity workflow solutions to successfully localize and characterize crystalline defects, electrical failures, and physical failures.



Auxiliary inverter
Smart, energy-efficient auxiliary inverters are driven by electric power

Main inverter
The inverter is used by the electric motor and regenerative braking, returning energy to the battery

Heater
Power switches connect the heater system to the HV battery

On-board charger
The battery block is charged via an AC-DC converter module

HV-LV DC-DC converter
The DC-DC converter charges the conventional 12 V power supply net from the HV battery

Battery management system
Lithium-based battery systems are monitored for safety

Wide-bandgap power devices are playing a major role in many applications – currently around 25%, including electric vehicles. The compounded annual growth rate is predicted to grow from 2023 to 2030.*

** Source: Consegic Business Intelligence, 2023*

Crystalline defect analysis

Today's compound semiconductor wafer substrates depend on some form of epitaxial growth, in which a crystalline film with a well-defined orientation is grown on a crystalline substrate or a film of a different material to create a heteroepitaxy.

During epitaxial growth, crystalline defects on the substrate, such as threading dislocations, can extend into the epitaxial layer, **potentially leading to catastrophic failures**. This extension is primarily caused by a lattice mismatch between the grown layer and the substrate.

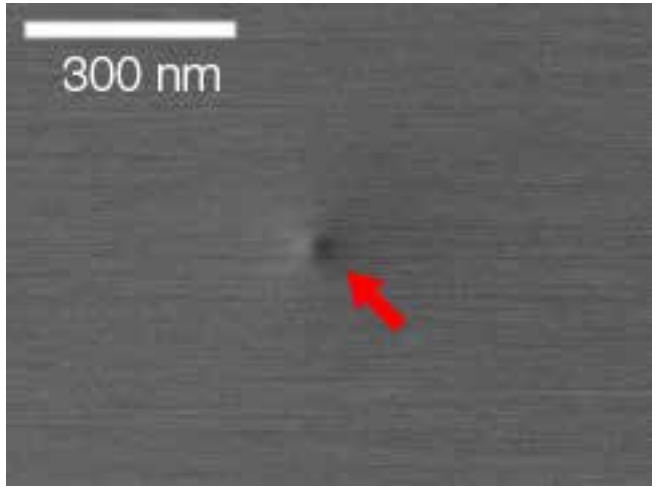
To identify potential issues, a high-efficiency workflow using **electron channeling contrast imaging (ECCI)** with a Thermo Scientific™ Apreo 2 SEM and Thermo Scientific Maps™ Software automates data acquisition, offering an optimal solution for characterizing crystalline defects in compound semiconductors.

Thermo Scientific Apreo 2 SEM

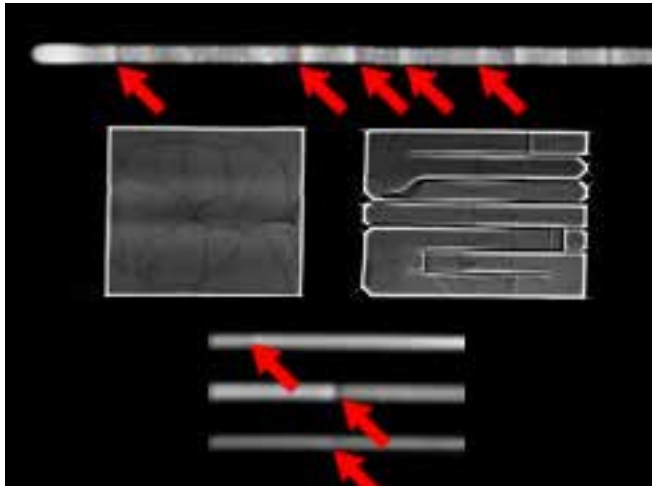
- Characterize surface layer defects with high-performance, sub-nanometer resolution SEM imaging
- Quickly and easily set up ECCI to identify substrate defects using PivotBeam mode
- Accommodates a wide range of sample types

Thermo Scientific Maps Software

- Visualize large areas with automated (tile and stitch) acquisition at any magnification
- Integrated data acquisition, annotation, and analytics



Near-surface ECCI technique shown on monocrystalline blanket layers.



Near-surface ECCI technique shown on patterned structures.

Fault isolation

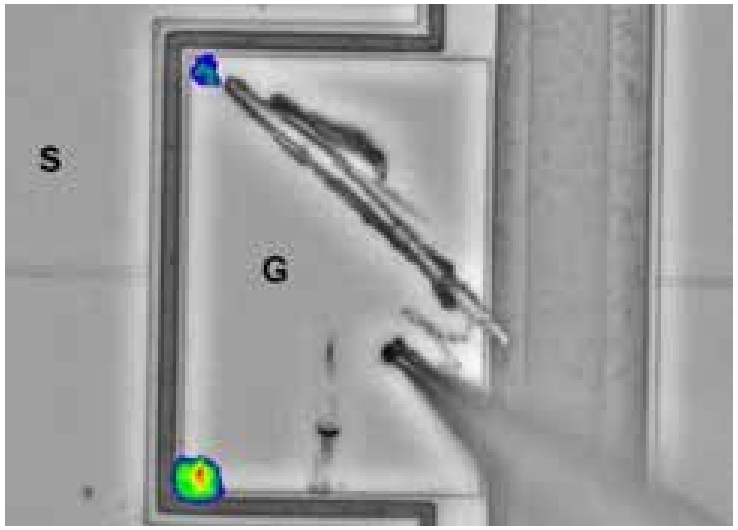
Tools optimized for maximum sensitivity are essential to localize challenging defects.

Coarse fault isolation is the initial step in the workflow and is used to identify heat signatures on bare die, packaged die, or wafer to locate the region of interest. The Thermo Scientific ELITE™ System uses lock-in IR thermography to **precisely characterize and localize buried defects**.

Fine fault isolation is achieved by removing metal layers obscuring the defect and **identifying the location with pinpoint accuracy** using a Thermo Scientific Meridian S System and optical fault isolation techniques such as optical beam induced resistance change (OBIRCH).

Thermo Scientific ELITE VX System

- Accurately locate critical, subtle defects in x, y and z with optimized sensitivity optics and higher signal-to-noise ratios
- Non-destructively localize defects in packaged die, bare die or complete modules
- Micron-scale x-y defect localization resolution and <50 µm z-depth accuracy



Hot spots detected by ELITE VX to locate defects under the device gate.

Thermo Scientific Meridian S System

- Precisely characterize transistor activity, electrical leakage, and other defect modes
- Non-destructively diagnose faults using SLS/OBIRCH with active noise cancellation
- Analyze high-voltage power devices up to 3 kV

OBIRCH results from a test chip showing high sensitivity on Meridian S.

Sample preparation

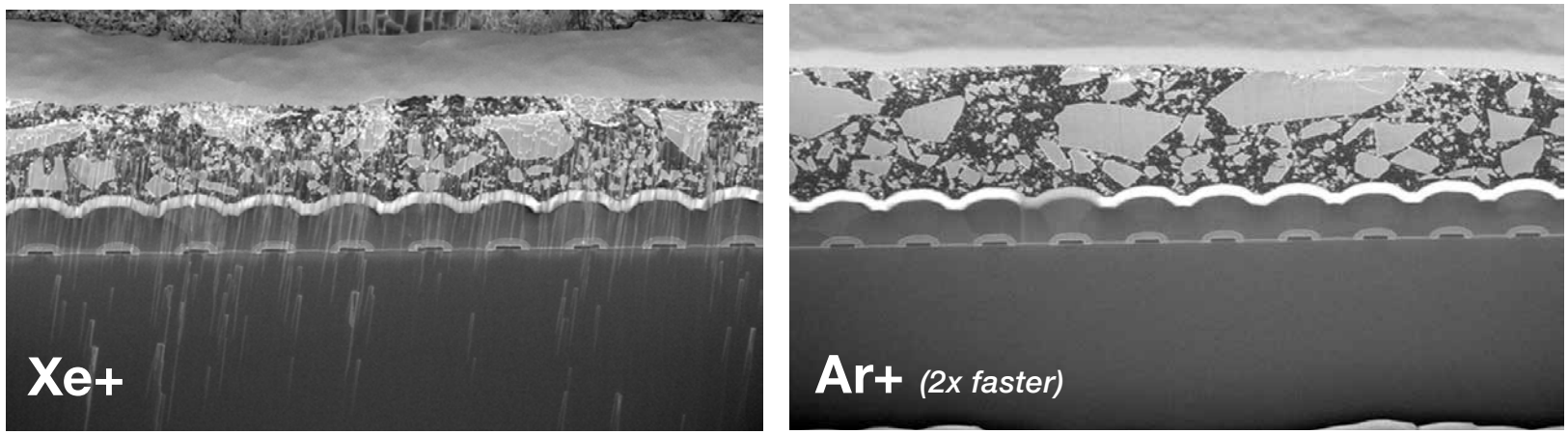
Rapidly preparing high-quality samples requires the versatility of milling with multiple ion sources.

Modern compound power semiconductors consist of both hard and soft materials, posing **challenges for sample preparation** using conventional techniques. However, the application of dedicated ion sources has successfully addressed this issue, enabling the creation of smoother surfaces for cross-section imaging and TEM lamella preparation.

For high-quality cross-sectioning and TEM sample preparation, the Ga-free Helios Hydra™ DualBeam uses multiple ion species to enable high-speed milling on the hardest power device materials. The Helios Hydra DualBeam also provides automated delayering to uniformly remove metal layers and expose buried defects for detailed electrical analysis.

Thermo Scientific Helios Hydra DualBeam

- 2x faster, Ga-free, cross-section milling utilizing switchable Xe, Ar, O, N ion species
- Precise in situ SEM cross-section imaging with sub-nanometer resolution Thermo Scientific Elstar™ SEM Column
- Ga-free, high-quality, sample preparation for TEM analysis of gallium-sensitive materials



SiC MOSFET SEM cross-section comparison between Xe+ (left) and Ar+ (right). Ar+ provides a higher quality polished cut in half the time.

Imaging and analysis

To quickly generate meaningful actionable information, a combination of versatility and user-simplified advanced imaging is required.

TEM analysis is a powerful complement to failure analysis, **providing unparalleled insights** into failure causes such as strain while also providing a comprehensive understanding of defect propagation.

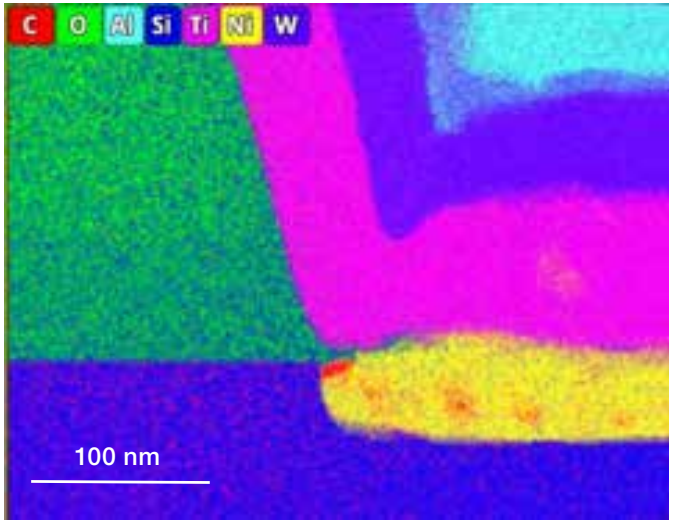
Using a TEM such as the Thermo Scientific Talos™ F200E, provides high-resolution imaging, metrology and structural information at the Angstrom scale. If larger scale visualization is required, a 3D reconstruction of the defect can be created using Thermo Scientific Avizo™ Software and SEM image data.

Thermo Scientific Talos F200E TEM

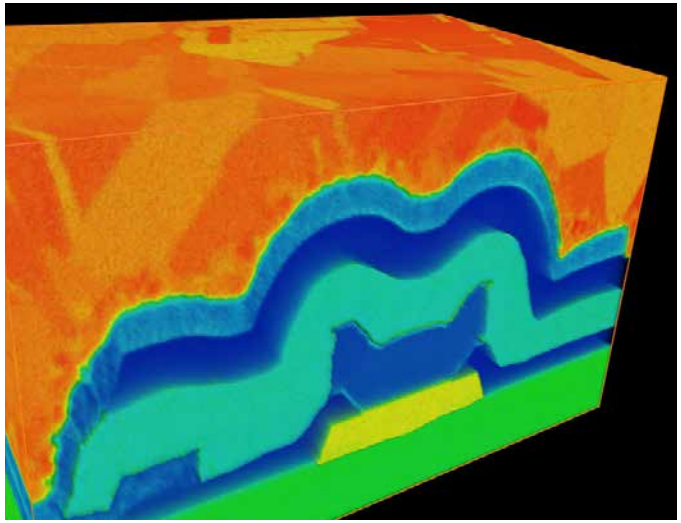
- Angstrom-resolution TEM reference data with low-distortion optics and drift-corrected imaging
- High-speed elemental analysis using EDS and EELS for characterization of defects and dopant profiles
- Easy-to-use, flexible operation

Thermo Scientific Avizo Software

- Automated image stack alignment enables visualization of nanometer-scale defects in 3D within large volumes
- Intuitive recipe creation, customization, automated replay
- Built-in measurements including counts, aspect ratios and orientations



SiC MOSFET STEM EDS analysis showing the gate metal to substrate interface.



GaN HEMT 3D rendering and segmentation shows individual structures and composition using Avizo Software.

About Thermo Fisher Scientific

Thermo Fisher Scientific is the leading provider of failure analysis, metrology and characterization solutions for nanoscale imaging and analysis of semiconductor devices. With more than four decades of experience working with the semiconductor industry, and with the broadest portfolio of localization, preparation, and analysis tools, Thermo Fisher provides the data semiconductor manufacturers need to accelerate development, inform process improvements, and maximize yields.

Our Mission

To enable our customers to make the world healthier, cleaner and safer.

Global support

A strong worldwide infrastructure is the foundation of our support delivery

- EM technical experts
- Field application engineers
- International warehouse network
- Extensive parts inventory
- Global Nanoports & training centers

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