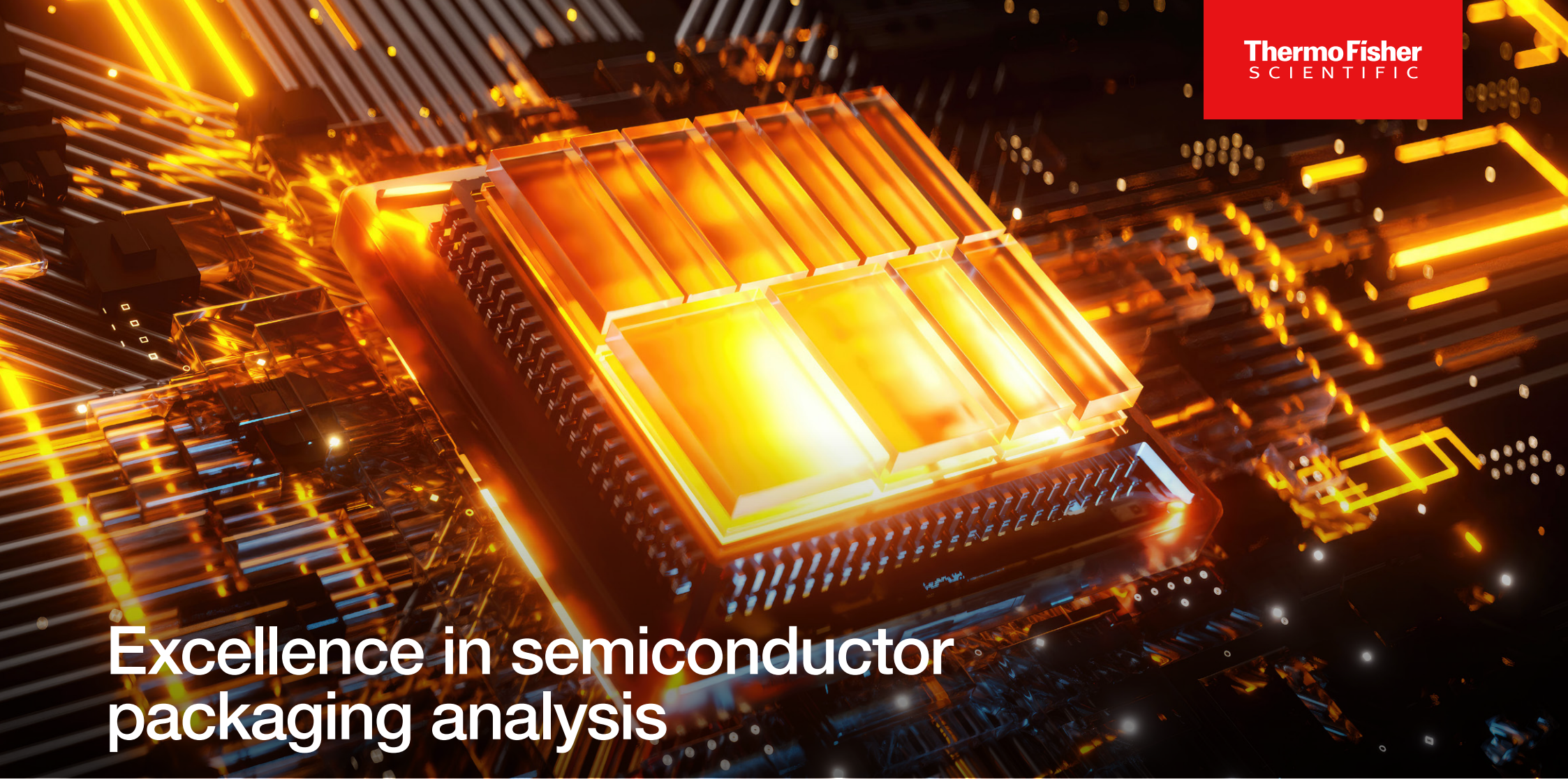


Excellence in semiconductor packaging analysis

Overcoming the challenges impacting semiconductor packaging development

thermo scientific

Challenges

The semiconductor packaging roadmap is rapidly advancing in performance and complexity. Whether a device incorporates chiplets, through silicon vias (TSV), µbumps, organic interposers, or ball grid arrays (BGAs), **multiple packaging challenges** impose significant impacts on failure analysis labs:

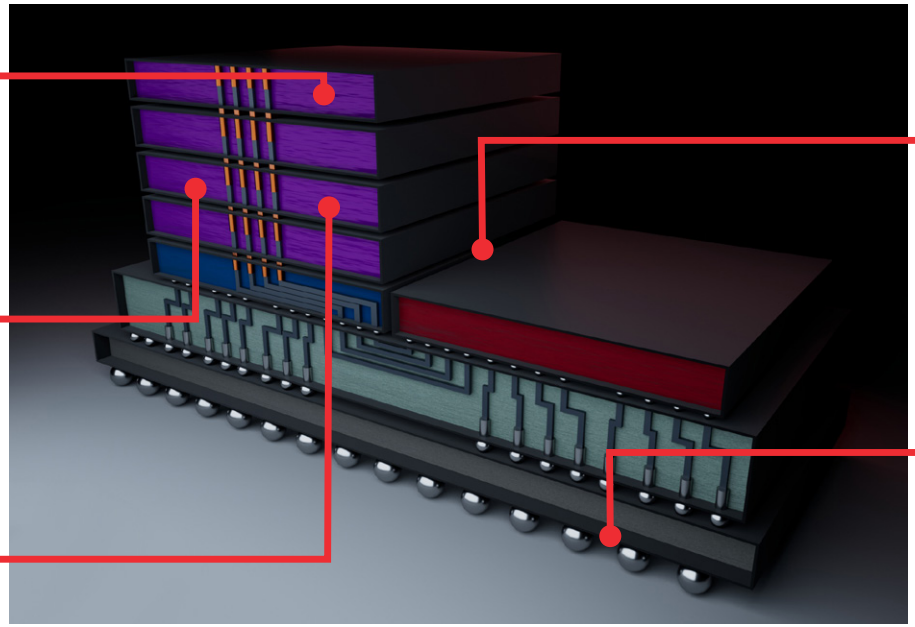
- 3D volumes—Defects are now buried in larger volumes of 3D material, making localization difficult. Defects may not be visible in X-ray. Preparation of samples for high-quality analysis requires high-quality, high-speed material removal.
- Materials—The complex combinations of hard and soft materials found in assembled die require new milling and sample preparation solutions.
- Packaged die costs—When die reach the test, assembly, and packaging stages, the sunk costs are enormous. Solving defects quickly is more critical than ever.

Solutions

At all major global labs, our electrical fault analysis (EFA) and physical failure analysis (PFA) workflows are relied upon to **solve these challenges**. They are relied upon for root cause analysis whether the defect is within a die or in the package itself. They provide reliable data with the fast turnaround times that industry leaders depend on.

The Thermo Scientific™ ELITE System's defect localization uses lock-in thermography for high-resolution defect localization and 3D insights into device performance. After localization, samples typically go to PFA and the Thermo Scientific Helios Hydra™ DualBeam for SEM cross-section analysis, delayering for nanoprobing, or precision sample prep for TEM analysis.

For root cause answers, the Thermo Scientific Talos™ F200E TEM delivers highly repeatable sub-nanometer imaging and elemental analysis. Thermo Scientific Avizo™ Software tools complete the full packaged die FA solution space. They provide efficient, high-quality, 3D visualization of SEM or TEM data, allowing you to rapidly pull key details from large volumes of data.



Die-level defects
Heterogenous packaging is making resolution of in-die defects critically important

Wafer thinning & bonding defects
Bonding, grinding, CMP, stress cracks, and underfill issues are becoming increasingly common as die and wafers are thinned for packaging

TSV etch/fill issues
High-aspect-ratio TSVs are becoming more prevalent, requiring 3D FA and process control

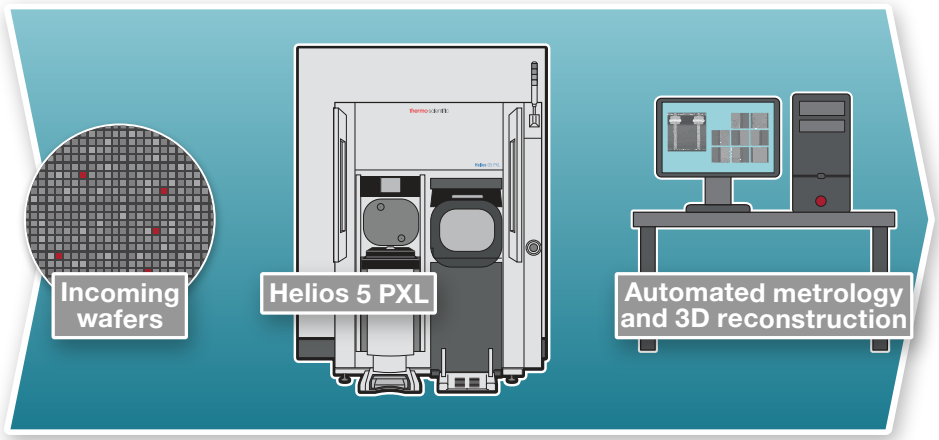
Hybrid & direct bonding
Nanometer-scale alignment precision and interface integrity (diffusion, delamination)

Bump interconnect issues
Shorts, opens, protrusions, and misalignments all require more large-volume FA

Wafer-level packaging analysis

Analysis, metrology, and characterization

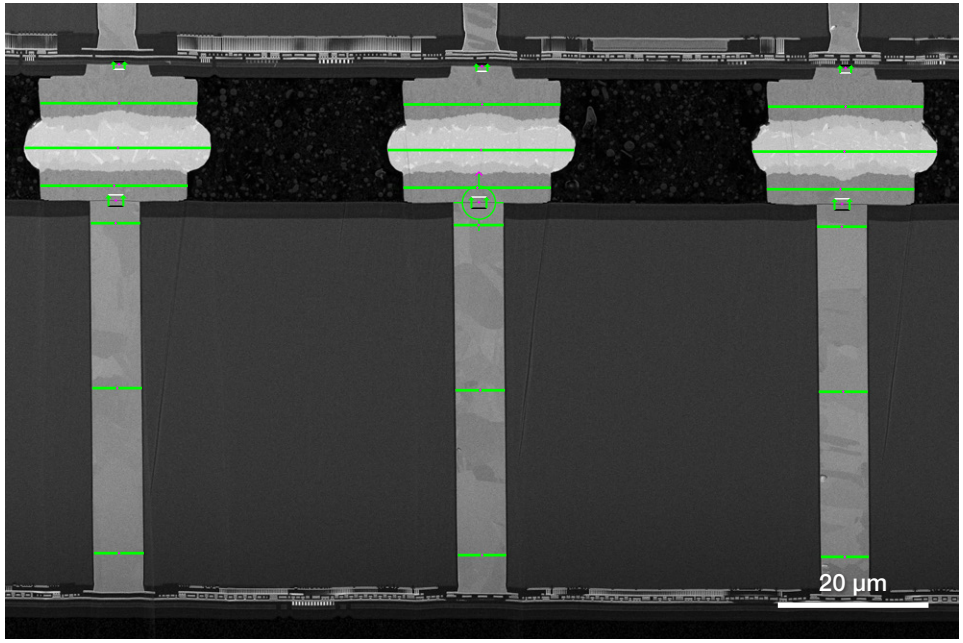
Computation-intensive applications such as AI are driving the increased adoption of wafer-level packaging (WLP). However, WLP presents challenges during research, manufacturing, and testing. To optimize yields, engineers need to quickly identify and address CD and defect issues earlier in the manufacturing stages. This means gathering precise metrology and defect analysis data while the devices are still in the wafer form factor. The Thermo Scientific Helios™ 5 PXL Wafer DualBeam offers high-volume, cross-sectional SEM data with a high degree of automation and repeatability.



Automated site-specific FIB cross sectioning and SEM metrology

Thermo Scientific Helios 5 PXL Wafer DualBeam

- Xe^+ PFIB for fast, high-volume milling capability
- Wafer-level system to accelerate time to actionable data
- Coincident beam with tilt stage
- 2D and 3D metrology analysis



Top Pad	Bump	Bump Pad	Bump-Pad offset	Pad-Pad offset	TSV Top	TSV Mid	TSV Bottom
20.99	24.85	19.62	0.51	0.66	6.56	6.58	6.62

Precise metrology of TSV structures expressed in micrometers.

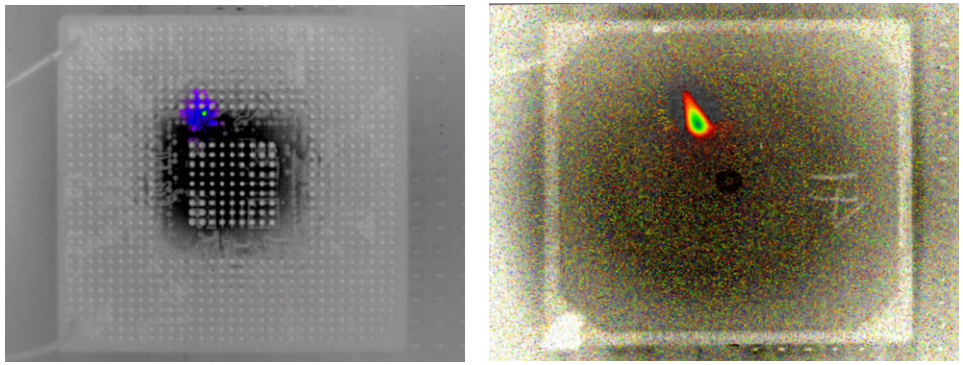
Packaged die analysis

Fault isolation and analysis

A rapid, precise solution for non-destructively identifying and localizing electrical defects in complex packaged devices is now essential.

Utilizing high-resolution lock-in thermography (LIT), the ELITE System offers a unique solution for non-destructively localizing electrical defects. It enables through-package, on-die, or even on-board defect localization for a wide range of defect types, including power or line shorts, ESD defects, current leakage, oxide damage, defective transistors and diodes, device latch-up, and resistive opens.

At the core of the ELITE System is its high-resolution, ultra-high-sensitivity IR camera that characterizes the amplitude and phase of the thermal response to precisely locate the defect in X, Y, and Z.



The ELITE System's high-sensitivity optical sub-system accurately pinpoints defects buried deep within a package in both X and Y using LIT amplitude data (left) and in Z using phase shift signal (right).

Thermo Scientific ELITE DX System

- Accurately locate critical and subtle defects in X, Y, and Z with high-sensitivity optics and maximized signal-to-noise ratio
- Non-destructively localize defects in packaged die, bare die, or complete modules
- Optional optical beam-induced resistance change (OBIRCH) for additional "in-die" localization resolution

Sample preparation

Highly flexible sample preparation is needed to meet the growing demand for packaged die FA. The Helios Hydra DualBeam's high-current, multiple-ion-source FIB-SEM offers a future-proof solution, with its ability to rapidly mill precisely targeted regions of interest and provide ultra-clean cut face quality.

Today's packaged die incorporate a wide range of materials and structures, including compounds with very diverse hardness, such as silicon carbide, gallium nitride, metals, oxides, and soft organic materials. A viable sample preparation solution must efficiently remove all these materials, while leaving a clean, artifact-free region of interest for subsequent analysis.

The Helios Hydra DualBeam features four switchable plasma ion sources (Ar^+, Xe^+, O^+, N^+) to perform the most challenging FA work, including large-volume SEM cross-sections, device delayering for nanoprobing, as well as precision, Ga-free TEM sample preparation.

Thermo Scientific Helios Hydra DualBeam

- Programmable ion sources enable high-quality milling of all common packaging materials including silicon, metals, oxides, compound semiconductors, ceramics, and organics
- Large-volume sample preparation (200x200 µm high-bandwidth memory cross-sections in under 45 minutes on sample sizes up to 200 mm diameter)
- Easy-to-use applications software for Ga-free sample preparation, device delayering, and curtain-free (rocking polish) cross-sectioning
- Optional features: *In situ* laser ablation module provides precise laser/FIB end-pointing

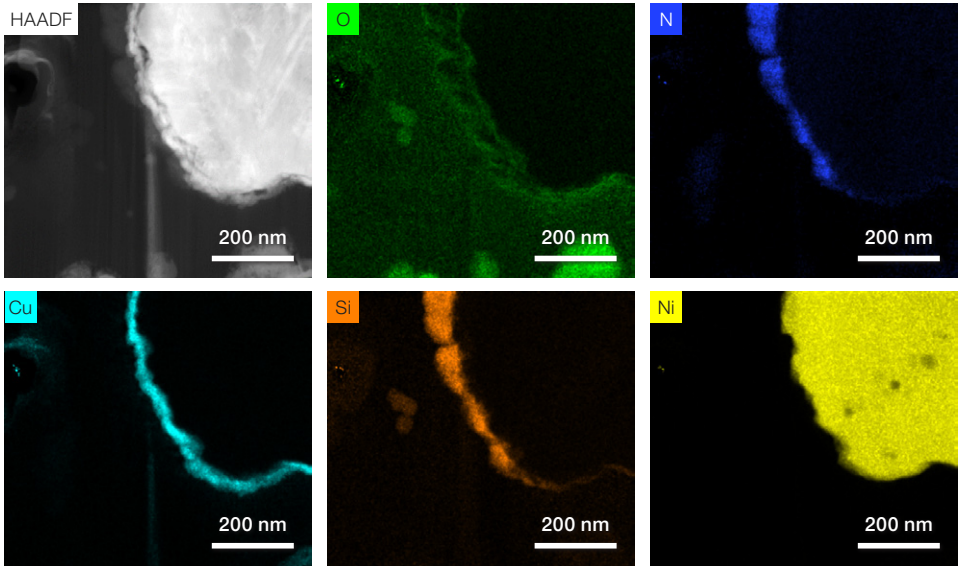
Imaging and analysis

Finding the root cause of nm-scale, “killer” defects requires fast, precise, repeatable analysis. Whether defects are coming from within the die or from packaging structures such as TSV, studying and fixing them requires high-quality imaging and elemental data. Normally, this requires highly skilled operators and many hours of work; however, the Thermo Scientific Talos F200E (S)TEM makes advanced analysis routine, enabling FA engineers to get high-resolution TEM answers quickly with minimal operator input.

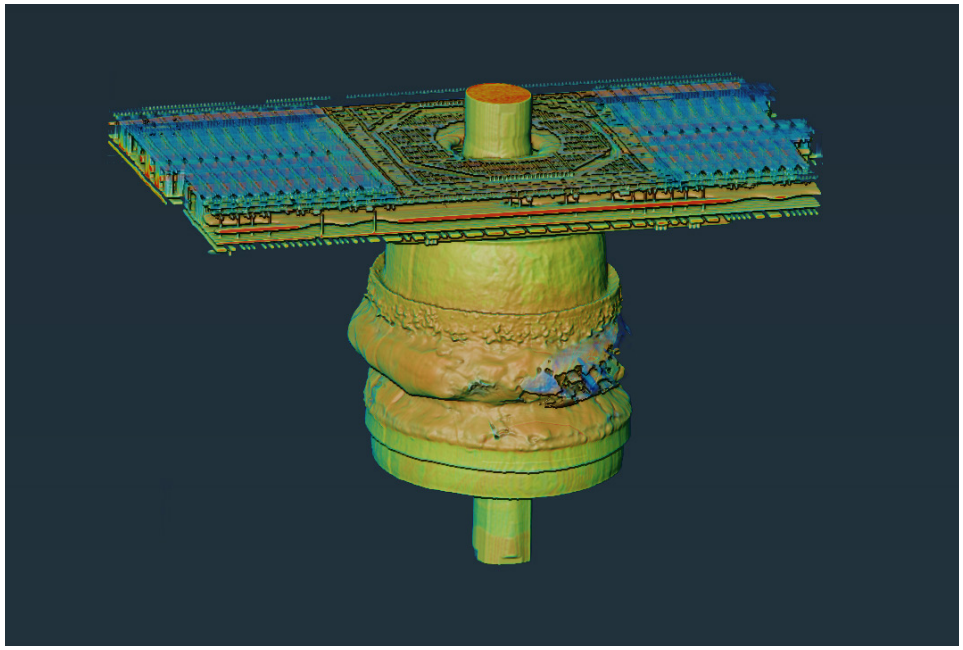
Whether the packaging analysis is done on a SEM or in a TEM, the visualization of small defects within large 3D volumes is sometimes required. This is easily achieved with Thermo Scientific Avizo Software. Avizo Software can rapidly reconstruct SEM or TEM image data into a high-quality 3D model for further analysis.

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



Talos F200E Super X EDS image showing chemical composition of device.



Avizo Software-reconstructed 3D model of a TSV-µbump-DRAM stack. Size: 50x35x25 µm.

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

Avizo Software capabilities

Duration 1:08

Service and Support

Your partner in service, across the lifetime of your system.

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

Scan this QR code to explore more about advanced packaged die analysis.

Learn more at **thermofisher.com/emserviceandsupport**