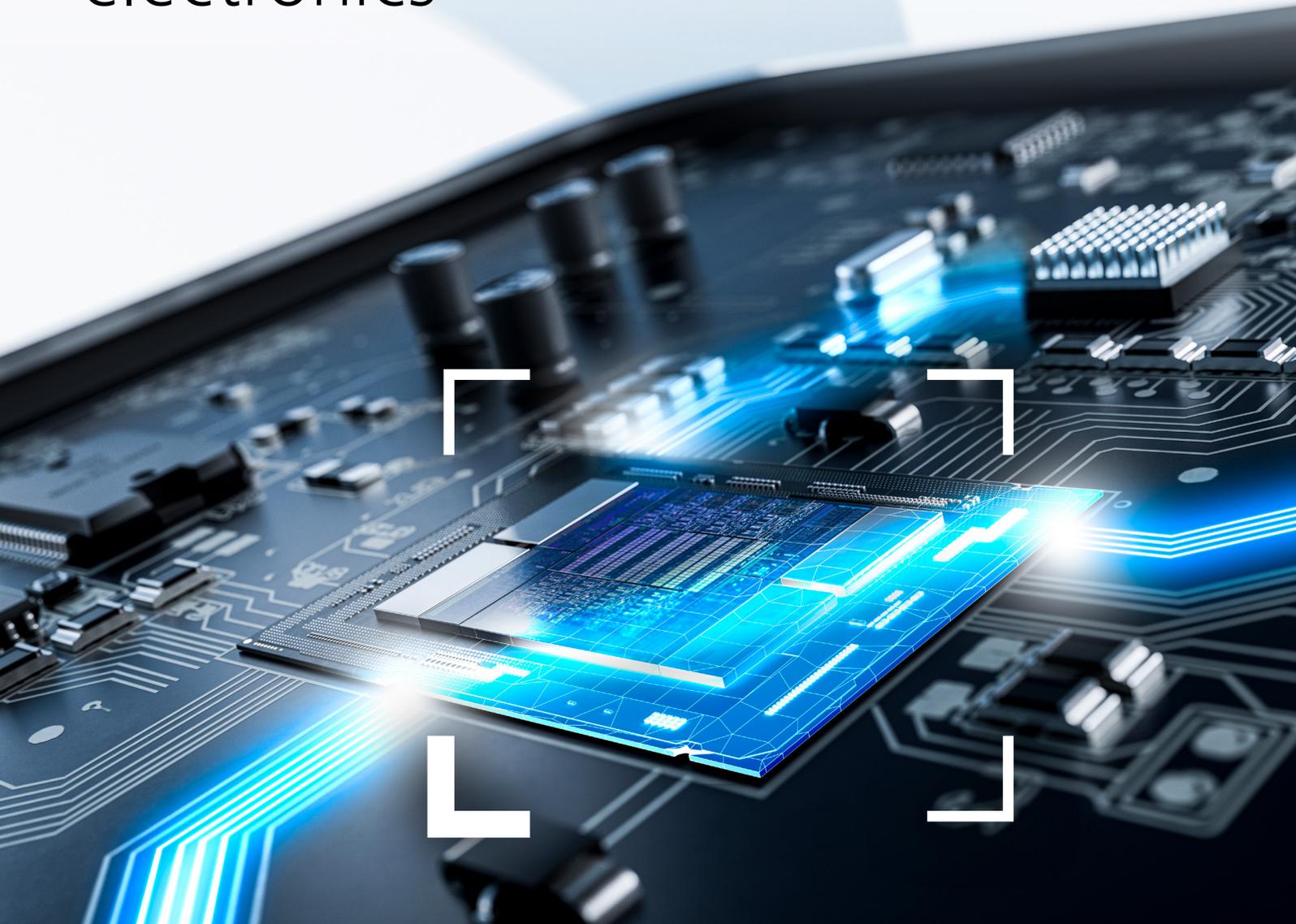# Accelerating Digital Transformation and Innovation
for semiconductor electronics

ZEISS Solutions for Semiconductor Development, Manufacturing, and Analysis
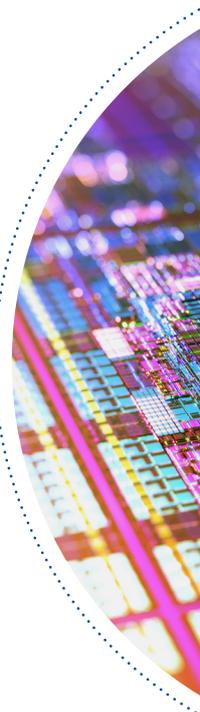
ZEISS

Seeing beyond

Enabler of Technological Progress
How ZEISS is driving digitalization

Digital technology is used everywhere in our modern economy. The semiconductor industry faces the challenge of producing ever smaller, more powerful, and more energy-efficient chips. Key to this chip scaling challenge is the perpetuation of Moore's Law, with EUV lithography acting as a cornerstone of advanced semiconductor manufacturing.

These devices ensure the proper functionality and regulation of many components in fields ranging from the automotive industry to consumer markets. There is therefore great demand for high-performance, defect-free chips. Product development must also be accelerated in order to achieve faster time to market. As a result, every stage in the design-to-production cycles of highly complex devices must be swiftly ramped up to ensure high-yield processes.

ZEISS powers the technology of tomorrow, supporting chip manufacturers worldwide when it comes to high-precision nanometer-scale optics and photomasks for semiconductor production. Intelligent workflows use advanced microscopy solutions and software to rapidly resolve critical issues affecting the manufacturing yield and device performance. And innovative industrial microscopy and metrology solutions enable inspection and top-level quality assurance for even greater productivity.
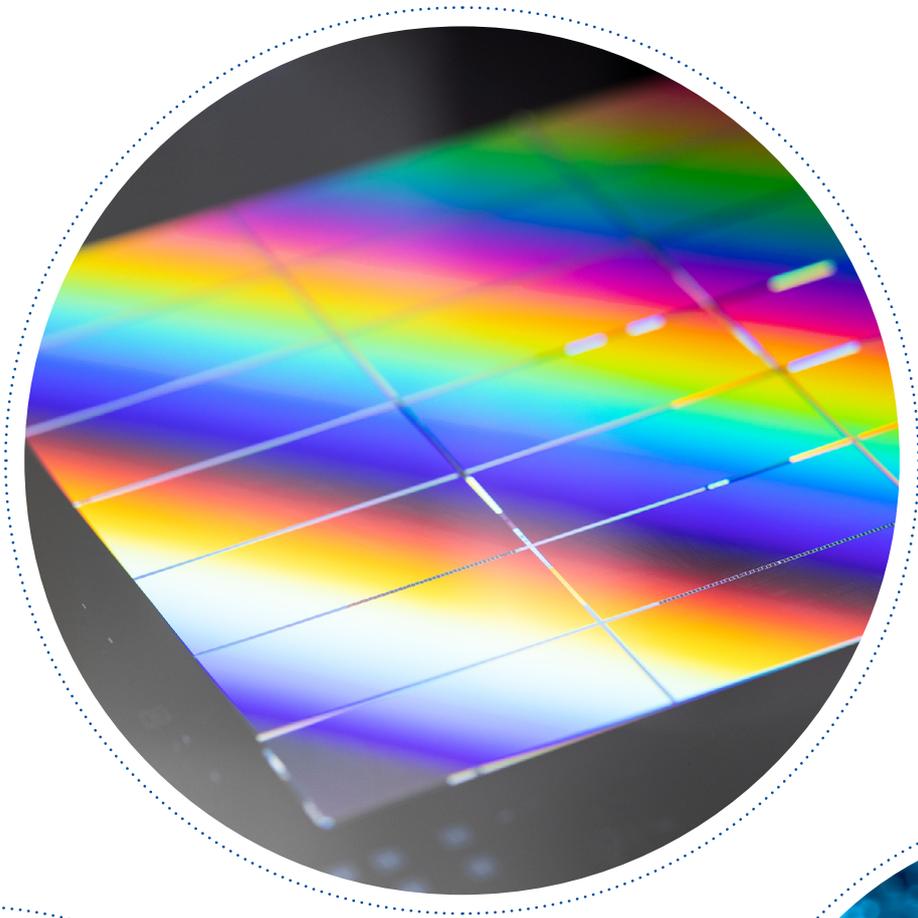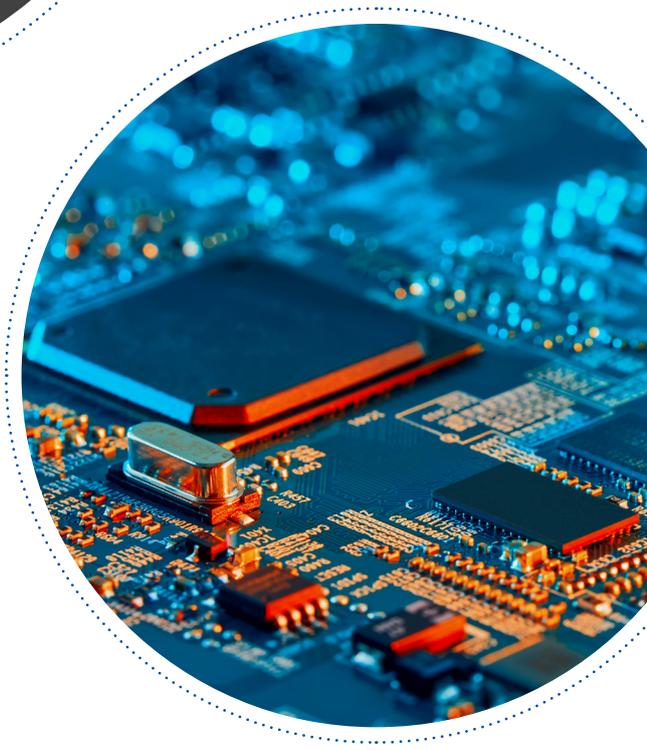
Photomasks for
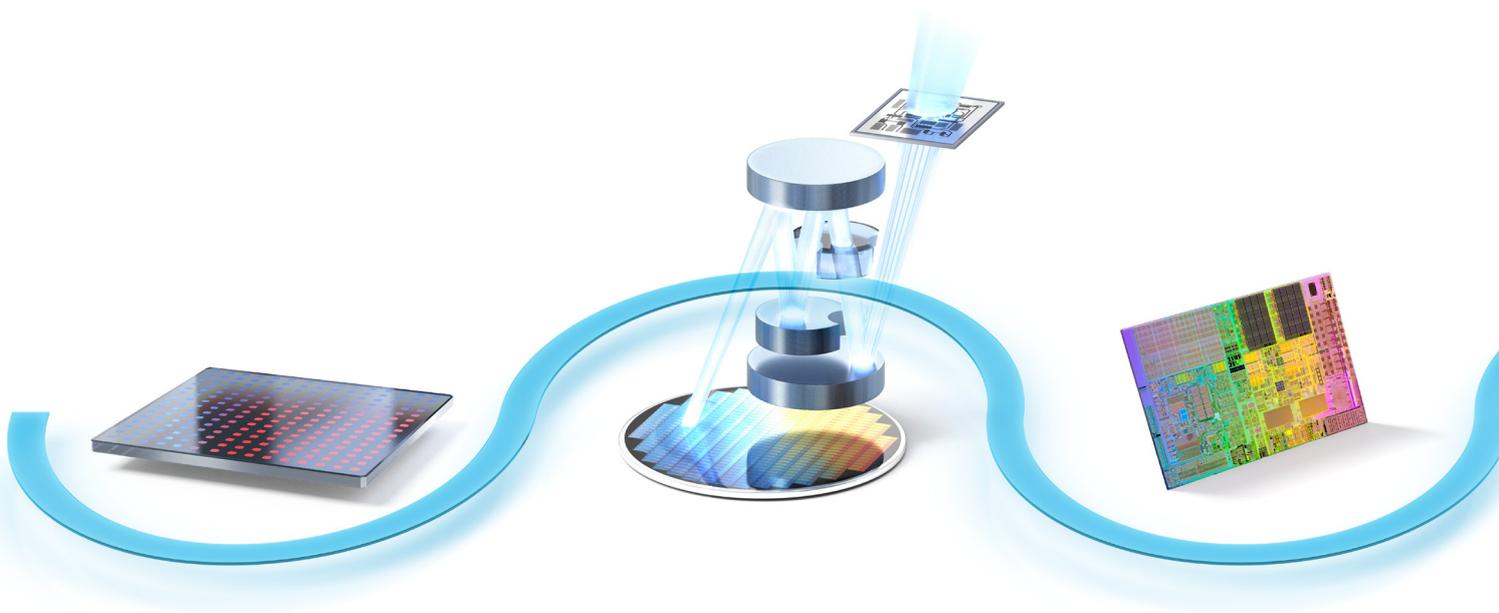EUV lithography
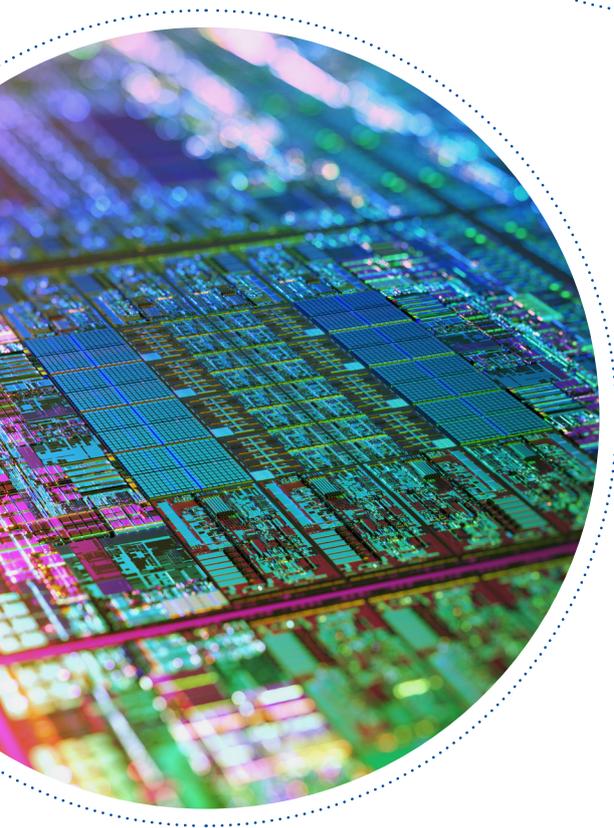
Patterned wafer

Component assembly
on a PCB

Semiconductor Development, Manufacturing, and Analysis
ZEISS solutions for every step

Chip manufacturing is a complex process. Each step requires advanced technology to aid the development, characterization, process optimization, metrology, and quality assurance needed for the manufacture of reliable electronics. This is essential for meeting the increasing demands of the digitalization that touches every aspect of life in our interconnected world.

ZEISS provides a host of solutions across the entire manufacturing chain. This ranges from the production of perfect photomasks and EUV optics for lithography through to advanced microscopy and metrology solutions for process control, inspection, characterization, and quality. As a partner to numerous companies in the semiconductor industry, ZEISS ensures the production of reliable high-performance electronic devices.

Photomask
Manufacturing
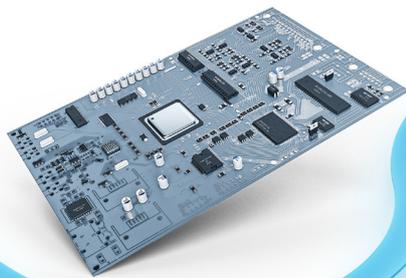
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Lithography
Optics

Page 8 / 9

Wafer/Die Characterization
and Failure Analysis

Page 10 / 11

Package Development
and Failure Analysis

Assembly and
Integration

Metrology and
Quality Assurance

Ø 6.684

11.61

58.74

Photomask Manufacturing

The ongoing technological evolution in integrated circuits (IC) is driven by exponential growth in computing power and data transport. This is expected to accelerate further in the coming years with the advent of artificial intelligence. Power consumption and computing performance will be key drivers for improved architectures and further increases in pattern density.

The photomask is a key element in semiconductor manufacturing. Defect-free structures are a prerequisite for the production of high-end microchips used in a wide range of applications.

Challenges

- Ever smaller feature sizes and new lithography techniques such as EUV lead to ever tighter photomask specifications
- Photomasks have to be defect-free and in-spec to enable the manufacturing of high-performance microchips

ZEISS Solutions

- ZEISS offers a wide range of solutions along the mask manufacturing chain to enable the production of defect-free photomasks
- Includes mask registration metrology (PROVE), mask tuning (ForTune), repair of hard and soft defects (MeRiT, PRT), mask qualification (AIMS)

Portfolio

Photomask Solutions
ZEISS PROVE
ZEISS ForTune
ZEISS MeRiT
ZEISS PRT
ZEISS AIMS

Detailed information on page 18 – 21

Application Examples

Photomask defect before repair: *The SEM image captured with ZEISS MeRiT (on left) indicates the defect in the pattern, while the aerial image from ZEISS AIMS (on right) shows how this translates to wafer printing on the EUV photomask.*

Photomask defect after repair*: ZEISS MeRiT supports reliable mask repair and defect correction via gas-assisted electron beam lithography (on left). The aerial image captured with ZEISS AIMS (on right) enables the user to verify the quality of the repaired defect.*

Lithography Optics

The perpetuation of Moore's Law has driven the development of ever smaller transistors in engineering and manufacturing technology. EUV lithography has been introduced to the market to address the stringent requirements for manufacturing next-generation logic and memory devices. The challenges involved in manufacturing the different components for EUV are pushing the frontiers of technology.

Challenges

- EUV lithography tools require mirrors featuring the highest precision and maximum quality
- Only ZEISS can produce the world's most precise mirrors
- Specialized, uniform, and atomic-scale precision thickness coatings are needed to increase the efficiency of mirrors

ZEISS Solutions

- The EUV scanner from ASML has been described as "the most technically advanced tool of any kind that's ever been made" (Mark Phillips, Intel Fellow and Director of Lithography)
- Research into what is now EUV lithography began over 25 years ago, since when ZEISS has applied for more than 2,000 EUV-related patents
- Extreme precision in the manufacturing of mirrors and atomic-scale precision in coating technology are critical components for this technological marvel
- ZEISS and ASML are already working on the next EUV generation, High-NA, which will enable even more powerful microchips

Application Examples

EUV technology incorporating high-precision optics with two functional modules

Portfolio

Lithography Optics
DUV (deep ultraviolet)
EUV (extreme ultraviolet)

Optics Modules
Laser components and modules
Optics and modules for wafer inspection

Gemini 2

Wafer/Die Characterization and Failure Analysis

Moore's Law and transistor scaling have continued with breakthrough technologies, process improvements, new materials, and complex device architectures. Ever-shrinking transistors and interconnects have made defect location and failure analysis more difficult and laborious. This adds to challenges in terms of reliability, yield, and manufacturing cycle time.

Microscopy solutions for inspection, characterization, and sample preparation have become critical analysis tools in determining the success rate and turnaround time for defect identification and root cause failure analysis.

Challenges

- Shrinking devices require inspection at the highest resolution with optimum contrast
- Advanced node devices demand electrical characterization without modifying or damaging the transistor properties
- Shrinking devices with complex 3D stacked geometries and new materials require an advanced sample preparation workflow for TEM analysis and 3D serial section imaging

ZEISS Solutions

- ZEISS GeminiSEM is an industry-leading FE-SEM enabling ultra-low voltage surface imaging and large field of view nanoprobing for the most demanding imaging and analytical tasks
- ZEISS Crossbeam FIB-SEM efficiently delivers high-resolution sample preparation, imaging, and analytics with unique workflows for 2D and 3D devices
- ZEISS Axio Imager light microscopes enable high quality widefield and confocal imaging with crisp contrasts and modular upgradability for handling everything from small components to 300 mm wafers with clean room compatibility

Portfolio

Electron Microscopy Solutions
ZEISS Crossbeam
ZEISS GeminiSEM

Light Microscopy Solutions
ZEISS Axio Imager
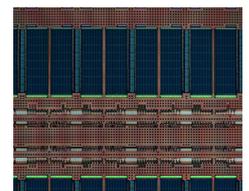
Application Examples
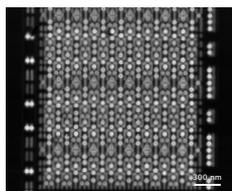
Passive voltage contrast at 0.6 kV with Inlens detector on delayered 7 nm SRAM
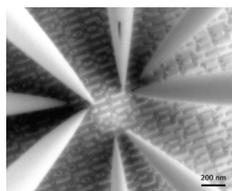
Imaging at 80 V for landing probes on 14 nm SRAM device with Inlens detector

3D visualization of FIB-SEM tomography dataset with voxel size 1 nm^3 of a 5 nm SRAM device acquired on ZEISS Crossbeam

Darkfield imaging on a 300 mm wafer with a 10X objective on a ZEISS Axio Imager Vario

Package Development and Failure Analysis

In the "More than Moore" era, transistor scaling alone is no longer sufficient for increasing performance and system miniaturization. Innovations in semiconductor packaging – such as wafer-level packaging, heterogeneous integration using TSVs, interposers, and hybrid bonding – have major potential for cutting costs and extending functionality.

At the same time, complex packaging architectures, feature size scaling, and increasing density of interconnects have introduced new challenges for reliability and failure analysis.

Challenges

- Fault isolation and defect localization are complex and laborious
- Non-destructive techniques do not provide a large field of view with sufficient resolution to account for increasing package sizes
- Physical analysis techniques for targeting defects in the 3D volume are slow and challenging
- Traditional failure analysis workflows lack the required combination of speed, resolution, and 3D information

ZEISS Solutions

- A unique 3D X-ray microscopy architecture with deep learning based reconstruction provides high resolution imaging with superior contrast breaking sample size and throughput limitation
- ZEISS Crossbeam FIB-SEM with integrated femtosecond (fs) laser provides fast, precise, and targeted sample preparation, shortening the time to result from days to hours
- The ZEISS Sigma and ZEISS GeminiSEM families of FE-SEMs provide distortion-free large field of view imaging with superior low kV performance and material contrast, enabling easy routine imaging and analysis

Portfolio

Electron Microscopy Solutions
ZEISS Crossbeam
ZEISS GeminiSEM
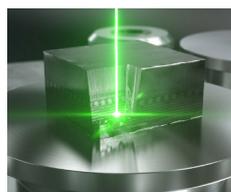ZEISS Sigma

X-ray Microscopy Solutions
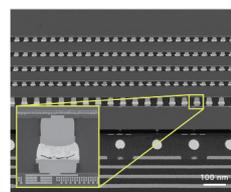ZEISS Xradia Context
ZEISS Xradia Versa

Application Examples

Sub-micron resolution 3D X-ray microscopy of IC package for non-destructive imaging of defects in package interconnects

High-throughput sample preparation targeting deeply buried microbumps in a 2.5D package with a gallium FIB-SEM and integrated fs laser

Distortion-free large field of view imaging with high pixel resolution of microbumps and RDL layers in 2.5D packages with ZEISS GeminiSEM

Assembly and Integration

From printed circuit board (PCB) to PCB assembly (PCBA), the manufacturing process comprises a number of complex procedures. Whether quality control of incoming substrate materials or surface finishing of PCBs, each step poses a number of quality assurance challenges.

One-stop quality solutions from ZEISS provide full coverage of the entire process, including substrate quality control, PCB manufacturing, and PCB assembly.

Challenges

- Quality control of surface roughness, morphology, and composition of incoming materials
- Inspection and measurement of trace width and via hole during PCB manufacturing
- Inspection of solder joint quality, surface defects, and failure analysis

ZEISS Solutions

- Optical inspection and measurement of trace width, weld quality, and metallographic section analysis
- Confocal imaging for analyzing surface roughness and through hole size with ZEISS LSM 900 Mat
- Rapid SEM inspection and compositional analysis of incoming materials, dry films, IMC layers, and corrosion with ZEISS EVO
- X-ray CT of pores and cracks in solder joints and laminates

Portfolio

Electron Microscopy Solutions
ZEISS EVO
ZEISS Sigma

Light Microscopy Solutions
ZEISS LSM 900 Mat
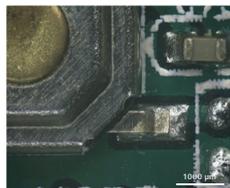ZEISS Visioner 1

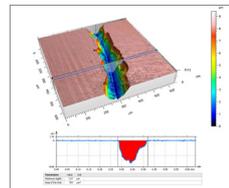**X-ray Microscopy Solutions**
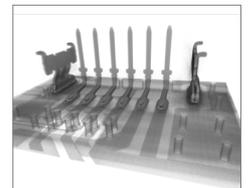ZEISS METROTOM
ZEISS Xradia Versa

Application Examples

SEM inspection of surface mount passive components

Optical inspection of PCB components with ZEISS Visioner 1

Surface roughness and profiling via confocal imaging with ZEISS LSM 900 Mat

Non-destructive X-ray imaging of a PCB with ZEISS METROTOM

Metrology and Quality Assurance

When manufacturing and assembling electronic and structural components in production environments, metrology and quality assurance are essential for meeting industry standards in terms of product performance and quality. Among the critical tasks are dimensional measurements, internal and external defect inspection, surface quality analysis, and verification with a master reference.

Speed and productivity must be complemented by accuracy and repeatability. ZEISS understands the specific manufacturing requirements and provides superlative tailored metrology and quality assurance solutions.

Challenges

- Highly efficient dimensional measurement for process control, ensuring the stability of the production line
- High-throughput inspection and measurement of components at different resolution scales in lens module assemblies and housing assemblies of connectors, phones, and wearables
- Inspection of internal alignment, dimensions, surface roughness, and defects such as pores or cracks in housing components and final assembly
- Fast inspection and verification of deviations or deformations affecting structural and housing components

ZEISS Solutions

- ZEISS CONTURA for high efficiency, accuracy, and repeatability in tactile dimensional measurements
- Multi-sensor metrology with ZEISS O-INSPECT for optimized tactile and optical measurements of various components in the assembly. Optical metrology with ZEISS O-DETECT for excellent optics, fast imaging, and various illumination options for every application
- Non-destructive X-ray computed tomography inspection with ZEISS METROTOM provides complete data analysis of components, including internal features that are not accessible with traditional optical or tactile metrology solutions

Portfolio

CMMs and Metrology Solutions
ZEISS CONTURA
ZEISS O-DETECT
ZEISS O-INSPECT

X-ray Microscopy Solutions
ZEISS METROTOM

Detailed information on page 18 – 21

Application Examples

X-ray computed tomography imaging and measurement of a base plug with ZEISS METROTOM
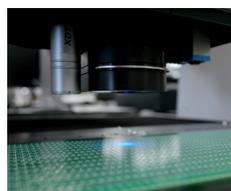
Optical measurement using ZEISS O-DETECT

Subsequent detailed analysis of the results in ZEISS CALYPSO

ZEISS Solutions
Portfolio

As a leading provider to the global semiconductor community, ZEISS offers a comprehensive portfolio of solutions. Powered by core technologies in imaging, precision engineering, and metrology, these innovations help the semiconductor industry meet the challenges of next-generation devices.

ZEISS provides unique photomask solutions for zero-defect operation, in-die metrology, critical dimension/registration, and overlay. Its light, X-ray, electron, and ion beam microscope systems support semiconductor manufacturing from wafer fabs through to packaging and assembly. These are complemented by metrology and quality assurance with CMMs, CT, and optical technologies, which power production monitoring, reliability, and systematic quality control in assembly and integration.

The sophisticated ZEISS software suite enables data correlation for connected instruments in order to streamline workflows, perform advanced image analysis with AI and machine learning tools, and deliver actionable insights that improve efficiency, productivity, and turnaround time.

Photomask Solutions

ZEISS PROVE
Photomask metrology

Measures image placement with sub-nanometer repeatability and accuracy. Pattern generator calibration, mask process control, and in-die metrology.

ZEISS MeRiT
Photomask repair

Single-platform opaque and clear defect repair on all photomask materials with top precision. Superior resolution and accuracy, no contamination.

ZEISS ForTune
Photomask tuning

Meets tightest mask registration specifications, achieving high yields, preventing excursion, and reducing process defect probability on wafer.

ZEISS AIMS
Aerial image measurement

Unique system for performing defect review, printability analysis, and repair verification on current and future photomask generations.

Electron Microscopy Solutions

ZEISS EVO
Conventional SEM for failure analysis and quality analysis

Routine inspection and failure analysis of PCBs, passive components, and modules.

ZEISS Sigma
Mid-range FE-SEM for failure analysis and inspection

Offers excellent user experience and higher productivity. Enhanced resolution at low voltages. Acquire analytical data twice as fast and with added precision.

ZEISS GeminiSEM
FE-SEM for highest demands in imaging and analytics

Easy imaging with sub-nanometer resolution and high detection efficiency. Ideal for nanoprobing and characterization of materials requiring low voltages.

ZEISS Crossbeam
FIB-SEM for high-throughput sample preparation

High-res sample preparation, imaging, and analytics. Unique workflows for 2D and 3D devices. Failure analysis turnaround in hours with fs laser integration.

Light Microscopy Solutions

ZEISS Stemi Stereo Microscopes
Routine inspection made easy

Inspection of PCBs and electronic components for quality assurance and failure analysis with large field of view and up to 50x magnification.

ZEISS Visioner 1
Digital microscope with revolutionary technology

100x more usable depth of focus for visualization of the PCB assembly and electronic components. All in focus, every time.

ZEISS LSM 900 Mat
Confocal laser scanning for 3D surface analysis

Inspection of surface roughness and 3D profiling on wafers, PCBs, and electronic components for inspection, quality assurance, and failure analysis.

ZEISS Axio Imager Vario
Wafer inspection with best-in-class optics

Modular platform for inspecting wafers up to 300 mm and large PCBs. Upgradable hardware and software modules for diverse inspection capabilities.
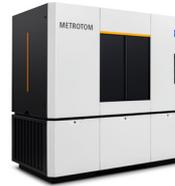
X-ray Microscopy Solutions

ZEISS BOSELLO
Robust defect detection

Automated or manual non-destructive 2D X-ray inspection for high productivity, quick loading and unloading, fast cycle times, and flexible applications.

ZEISS METROTOM
Handles entire components

Quality assurance with a single 3D computed tomography scan. Standard acceptance test, precision engineering, and sophisticated calibration for system traceability.

ZEISS Xradia Context
High-end microCT for packaging and components

Failure analysis and 3D inspection with high-quality imaging and upgradable modular platform.

ZEISS Xradia Versa
Industry-leading resolution and contrast

Outstanding failure analysis for semiconductor packaging. 3D X-ray imaging extends the limits of resolution and contrast.

CMMs and Metrology Solutions

ZEISS MICURA
Top precision for small parts

Ideal for meeting increasing accuracy requirements. Particularly suited to complex and compact components with tight tolerances.

ZEISS PRISMO
When precision matters the most

High-speed scanning with maximum accuracy in the measuring lab, full compliance with ISO quality standards, and no compromise on precision.

ZEISS CONTURA
Prepared for all challenges – today and tomorrow

Ideal for versatile measuring tasks thanks to mass technology, which allows tactile and optical sensors to be used on the same system.

ZEISS O-INSPECT
Expert in every discipline

For components requiring tactile precision plus an optical solution for surface-sensitive sections. Optimally measures each characteristic every time.
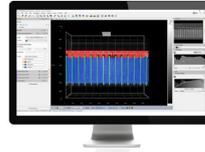
Software and Digital Solutions

ZEISS ZEN core
Software suite for connected microscopy

From materials lab to production: the most comprehensive suite of imaging, segmentation, analysis, and data connectivity tools for multi-modal microscopy.

ZEISS arivis
Comprehensive image analysis platform

Family of software products for multi-modal, multi-dimensional microscopy data that integrates and connects all image analysis pipelines.

ZEISS Quality Suite
Platform for metrology software and much more

Single-platform access to our 3D software. Read news articles, book extensive software training courses, and find add-ons for your metrology software.
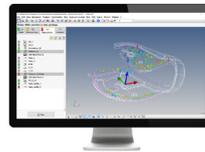
ZEISS CALYPSO
All-round software for dimensional metrology

Quick, simple, and reliable measurement of geometrical elements. Combines with ZEISS measuring systems and sensors for a powerful one-stop solution.

This portfolio is geared toward future growth in the electronics and semiconductor industry. ZEISS solutions shape the future of technology, powering constant advances in optics and related fields.

The Carl Zeiss Foundation, one of the largest German foundations committed to the promotion of science, is the sole owner of holding company Carl Zeiss AG. The company's significant sustainable investments in research and development lay the foundation for furthering its technological success and market leadership.

# Your Global Partner –
present in all regions

60

Sales & Service
Organizations

30

Production Sites

Spread across nearly 50 countries, ZEISS' global operations include around 60 sales and service companies, 30 production sites, and 30 research and development sites with over 38,000 employees. Our highly trained application specialists and service engineers maintain high standards to help the semiconductor industry meet the latest requirements. Dedicated application support is also available at every stage. With our worldwide network of spare parts hubs speeding up response times and supply chain logistics, priority is given to optimum system performance and maximum uptime.
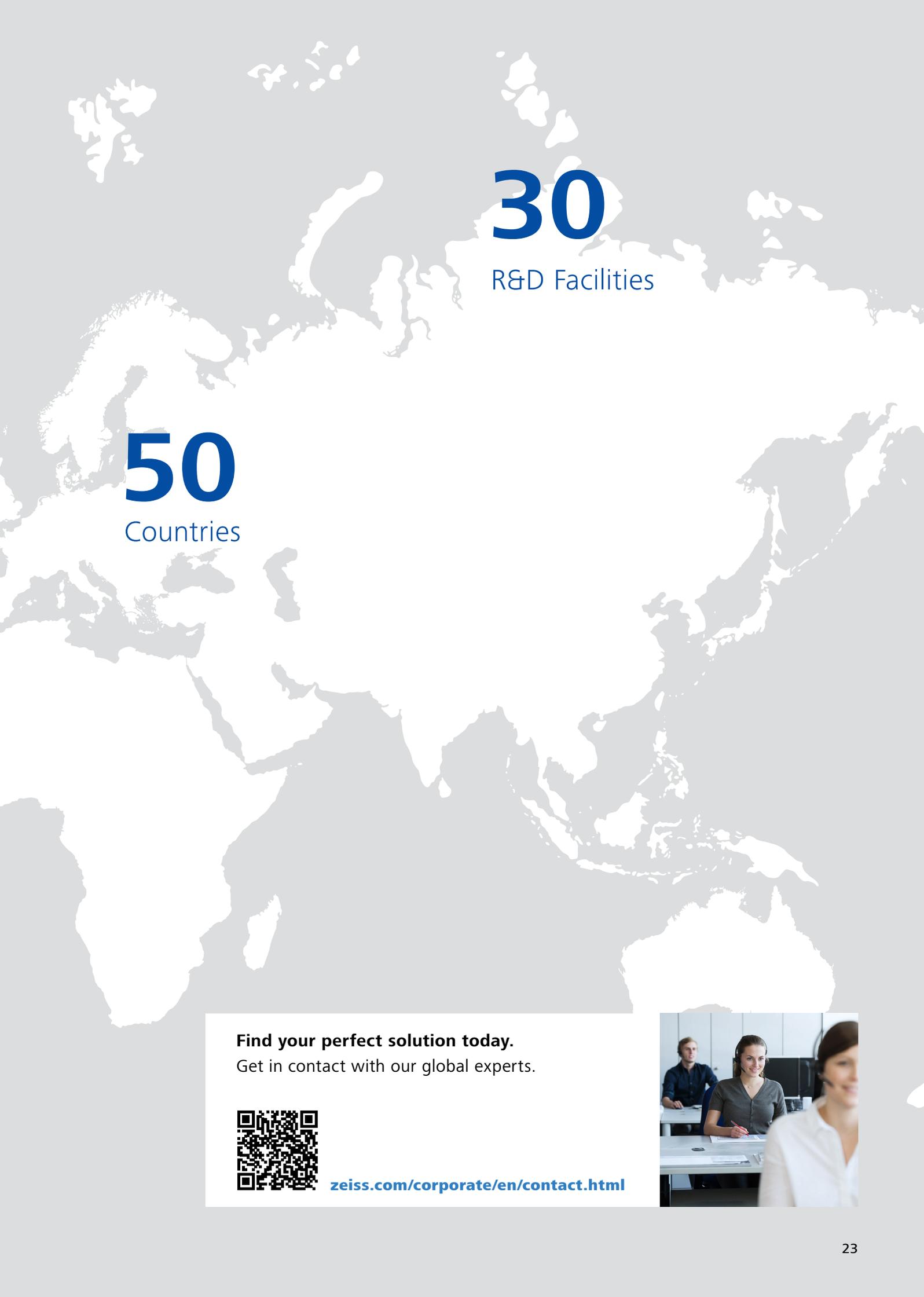
30
R&D Facilities

50
Countries

Find your perfect solution today.
Get in contact with our global experts.

zeiss.com/corporate/en/contact.html