Multi-modal characterization and advanced analysis options for industry and research

ZEISS Microscopy Solutions for Steel and Other Metals

zeiss.com/metals

ZEISS

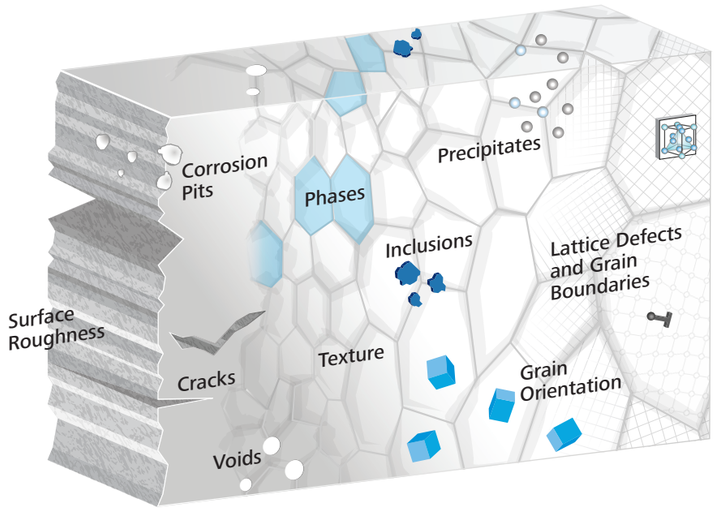
Seeing beyond

Beyond Metallography

Analytical microscopy for the research and quality control needs of the metals industries

Metallography has long been the focus of the metallurgist. Routine inspection and quality control tasks can be achieved rapidly and accurately using light and electron microscopy in industrially-focused workflows; now, multi-modal microscopy is capable of providing a vast array of analytical capability, *in situ* and often non-destructively. ZEISS offers solutions focused on both the industrial researcher and the quality engineer around five key areas: chemistry, crystallography, dimensional measurement, tomography, and determining processing parameters.

The ZEISS portfolio of light, X-ray and electron microscopes provides unique capabilities to solve both the routine characterization and advanced research and development problems of the metals industries, on multiple scales. Today, advanced analytical tasks can be accomplished in integrated and connected solutions using digital imaging, spectroscopy, crystallography, 3D tomography and data handling.



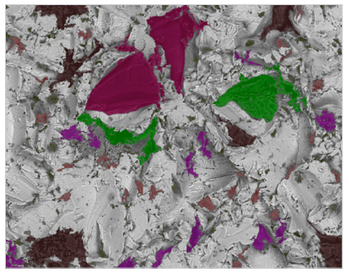
Metals characterization across length scales

Metals Research & Development
Chemical analysis

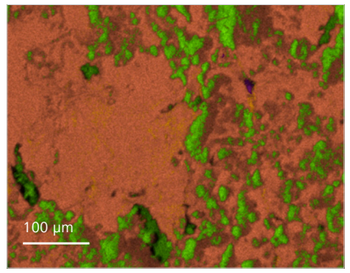
Elemental analysis of metals and metallic parts is critical in understanding the composition, purity and performance of metals. The ability to simultaneously image and chemically assess microscopic regions of a sample, such as inclusions and grains in real time, allows the researcher or failure investigator multiple dimensions of understanding.

Energy dispersive X-ray spectroscopy (EDS) solutions from a variety of providers are compatible with and frequently used on all ZEISS electron microscopes to provide a critical analytical data stream of the chemistry in distinct grains, phases, and contamination products present within metallic samples. Data can be represented in multiple ways to show elemental distribution and boundaries in both 2D and 3D.

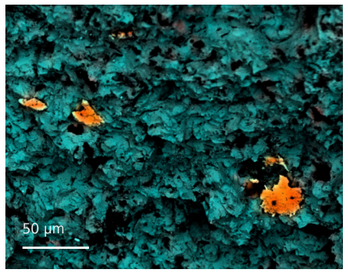
Wavelength dispersive X-ray spectroscopy (WDS) provides an additional layer of high precision trace element analysis on the electron microscope. Spectroscopic solutions on ZEISS electron microscopes therefore provide a complete spectroscopic solution alongside multiple additional crystallographic, structural and process data streams.



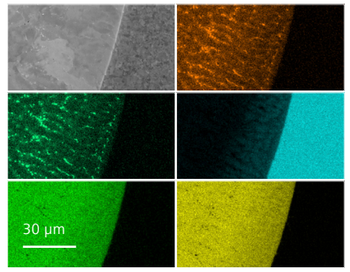
EDS map depicting categorized alumina particles on surface of S355 structural steel after grit blasting with F80 grit.
Sample provided by TWI Ltd UK



Rust identified (in green) through EDS on mild steel (in red)



EDS map of a fractured sample showing fragments of tin (orange) against the iron (blue) background. Sample courtesy of John Scott, West Mill Innovation, UK



EDS map across interface between Nickel 625 and Alloy 625 (a nickel alloy) and 8630 steel in a dissimilar weld, showing relative concentration of metallic elements across the weld. A secondary electron image is included for reference.
Sample provided by TWI Ltd, UK

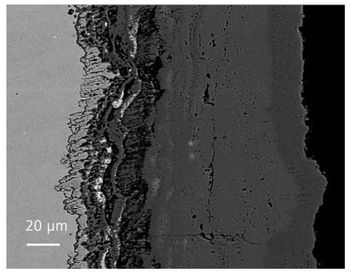
Applications of *in situ* chemical analysis include automated mineralogy of raw materials, particle analysis, weld mapping and inclusion characterization, particularly useful for fractography and predictive analysis.

Metals Research & Development
Surface corrosion and contamination

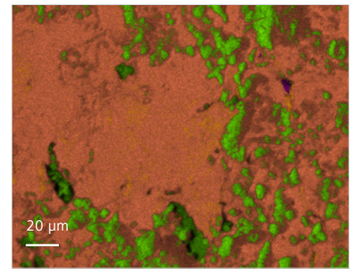
Characterize rust, corrosion and surface contamination on various length scales with the ZEISS portfolio of microscopes.

You can locate regions of interest in the light microscope and use unique correlative workflows to target your SEM investigations, or just use the full color navigation camera of the SEM to find contaminated regions. Rapidly understand the chemistry and morphology of impurities, corrosion and foreign matter on surfaces or in cross-sections using the vast array of imaging and analysis modes possible. Use integrated EDS analysis to rapidly provide spectral information and present your results alongside topography or elemental composition by use of the secondary electron and back-scattered detectors.

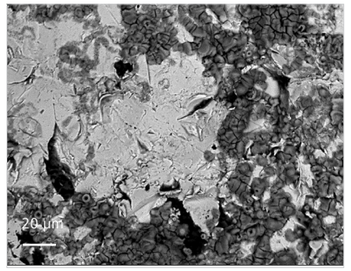
Expand your investigations into oxidation states using the optional cathodoluminescence detector or Raman spectroscopy accessory. Variable pressure or extended pressure modes are available for high quality imaging of non-conductive, uncoated or sensitive surface features.



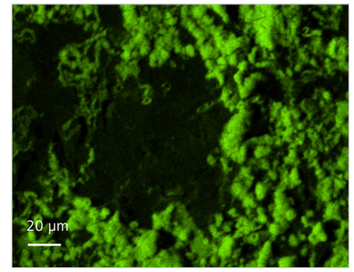
Corrosion scale formed during high temperature oxidation of 9% Cr steel.
Sample provided by TWI Ltd



Combined EDS map of corroded steel surface showing steel (red) and iron oxides (green).



Surface of corroded mild steel.



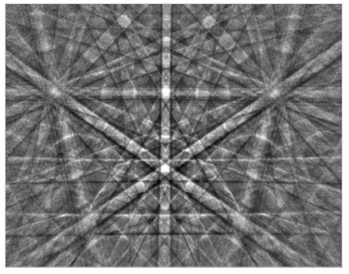
EDS map of oxygen concentration across surface of corroded steel.

Metals Research & Development
High-resolution crystallography

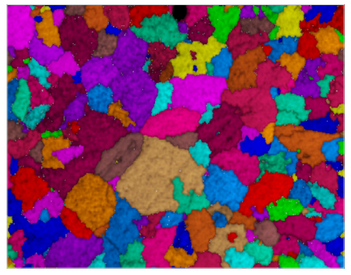
Discover grain size, crystal structure and crystal orientation at high resolution with optional EBSD on all our scanning electron microscopes. EBSD maps provide a wealth of crystallographic information on metals and materials, inclusions and precipitates. Alongside EDS, EBSD can perform phase analysis in steel and other metals, critical in the development of advanced steel where phase fractions of ferrite, austenite, martensite and other phases can be fine tuned and accurately characterized.

In situ thermomicroscopy and mechanical testing with live EBS is able to map ageing, phase transformations, strain and failure modes on a granular and grain boundary level, in real time from millimeter to nanometer scale, with optional thermal, tensile and compression stages.

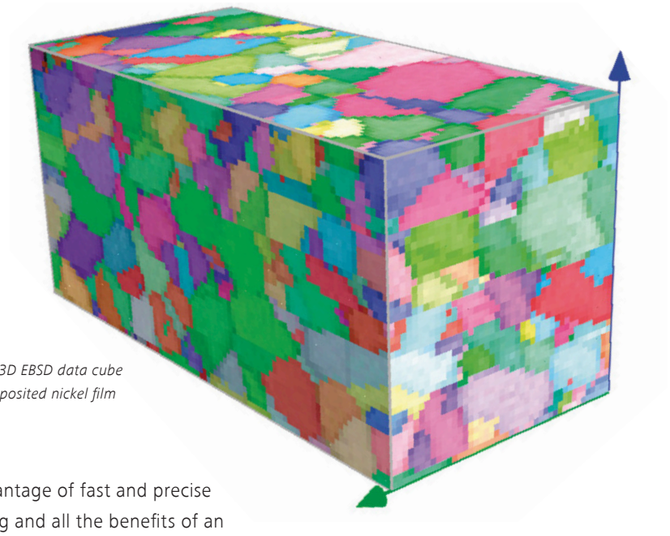
For the most advanced research applications demanding true nano-engineering and insight on a granular level, choose the ZEISS Crossbeam family of Focused Ion Beam SEMs.



High quality EBSD pattern.Image courtesy of Oxford Instruments Nanoanalysis



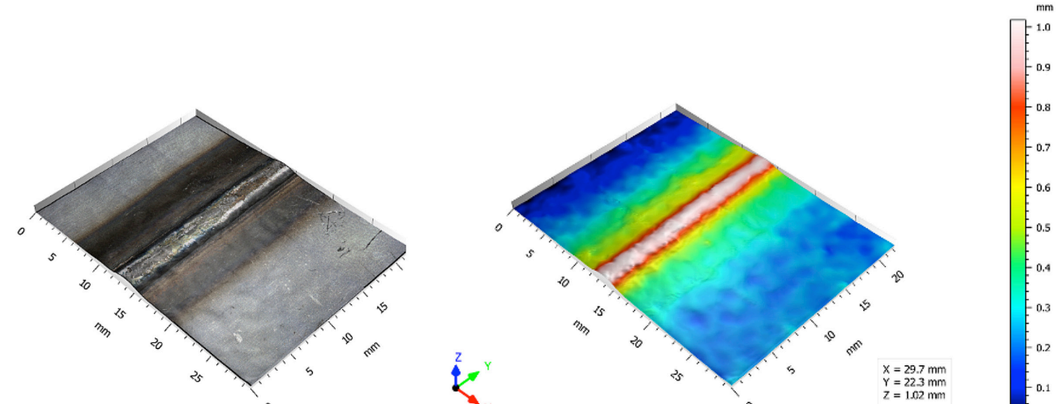
EBSD map of AlSi10Mg alloy with individual grains coloured



10x4x5 µm 3D EBSD data cube of electrodeposited nickel film

Take advantage of fast and precise ion milling and all the benefits of an advanced field emission SEM for high resolution 3D analytics, through EBSD, EDS, various imaging modes and other complementary analyses.

Metals Research & Development
Weld analysis

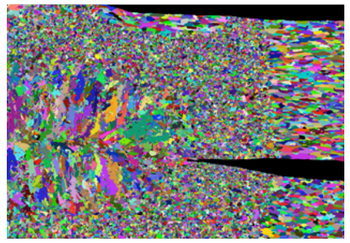


3D scans of root of autogenous nickel alloy weld using ZEISS Smartzoom 5 tilting and height rendering functions. Sample provided by Haynes International, Ltd

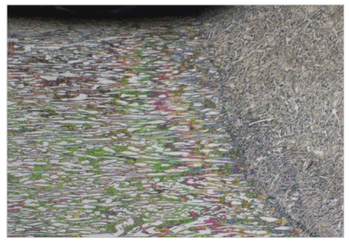
Multi-scale microscopy is an invaluable tool in characterizing and understanding metallurgy, chemistry and crystallography across welds.

Welding, brazing and forging operations are critical in development of the largest metallic structures that depend on the smallest micro-structures, particularly critical with dissimilar compositions, and joints are of critical importance in the integrity and performance of finished metallic parts. Unique textures and grain structures are formed by the aggressive heating, and subsequent annealing or quenching steps of metalworking.

From imaging microstructures and carrying out automatic topography measurement to performing non-destructive tomography and high resolution crystallography, the ZEISS portfolio of light, X-ray and electron microscopes deliver a unique breadth of characterization data for materials development and quality assurance alike, from the macro to the nano scale.



EBSD map of weld between two metallic sheets. Image provided by Oxford Instruments Nanoanalysis

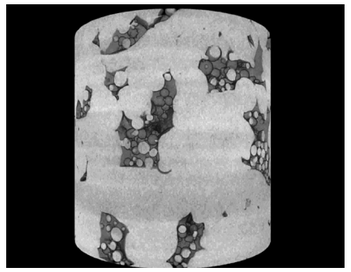


Parent to weld interface in duplex stainless steel. Sample provided by TWI Ltd

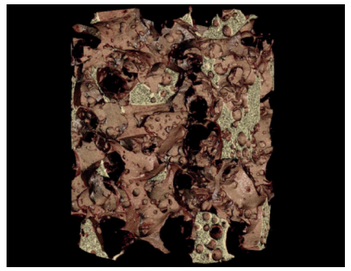
Metals Research & Development

Non-destructive tomography and crystallography

Achieve fast large volume 3D imagingand microstructural analysis using X-ray microscopy. The ZEISS Xradia family of X-ray microscopes achieve sub-micron 3D imaging of even large metallic structures in exceptional contrast, not possible with conventional CT (computed tomography), with software solutions that can reconstruct and explore your sample in submicron detail.

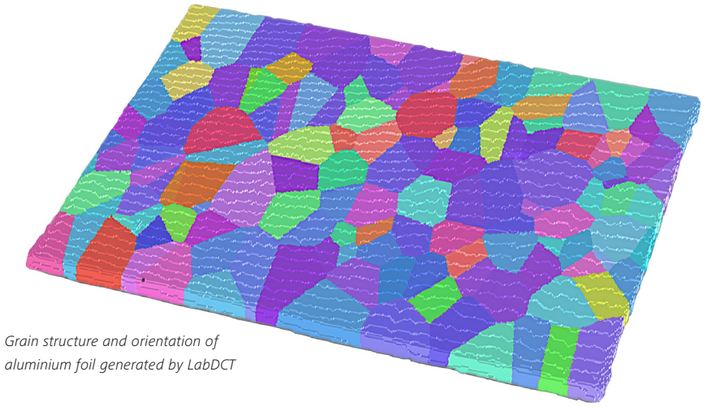


3D printed part from powder steel: Solid domain. Sample courtesy of NIST



3D printed part from powder steel: Pore domain. Sample courtesy of NIST

Combine ZEISS Xradia 520 Versa 3D X-ray microscope with the optional ZEISS LabDCT package, the first laboratory-based crystallography option for computed tomography, extracting 3D crystallographic information directly from metals, alloys and any other polycrystalline materials. This enables you to combine crystallographic information with absorption or phase contrast tomography, revealing precipitates, porosity and structures.



Grain structure and orientation of aluminium foil generated by LabDCT

Identify grain orientation and microstructural features in your sample volume such as defects or precipitates. High resolution, non-destructive 4D studies are made possible by resolution at a distance (RaaD) full sample imaging for *in situ* experiments, not possible with conventional CT.

Routine Analysis Tasks

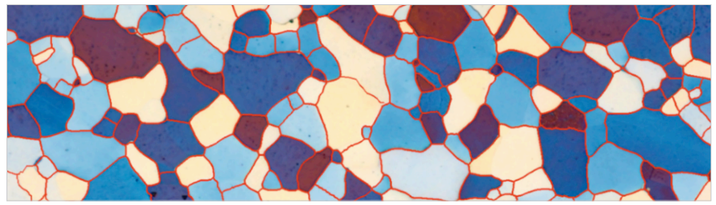
Grain size analysis

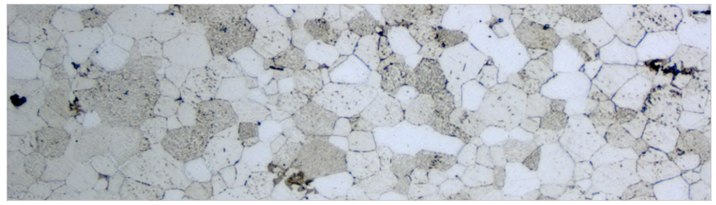
Analyze grain size automatically and precisely with ZEISS ZEN Grains image analysis module. Forming the basis of quantitative microstructural assessment, grain analysis is the essential metallography module.

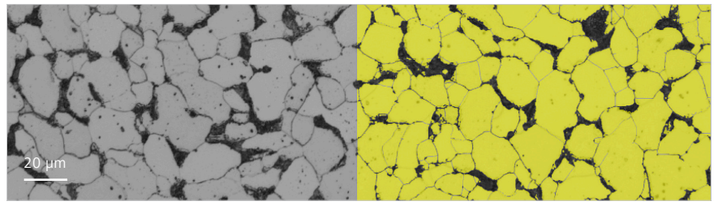
Three measurement modes are available: comparative diagrams, a purely interactive method, the semi-automatic intercept method and the fully automatic method, which automatically reconstructs grain boundaries and calculates individual grain sizes.

ZEISS solutions allow the metallurgical quality control or research laboratory to implement a turnkey, fully automated grain analysis solution, eliminating potential inaccuracies and subjectivity introduced by the human factor, while complying with ASTM E112 or other international standards. Data are automatically archived and reports automatically generated, ensuring accurate, rapid, repeatable results saving valuable time and money.

Plus, the unique optional ZEN GxP module adds a fully auditable data traceability and integrity solution to materials microscopy for the first time.







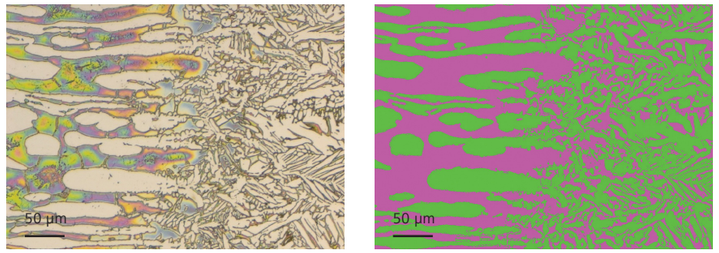
Measurements of grain size in ferritic steels

Routine Analysis Tasks
Multiphase analysis

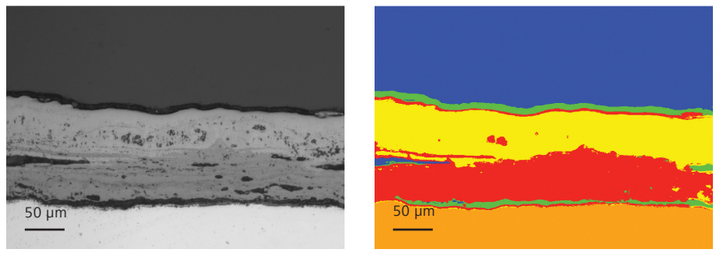
Phase analysis of metals and alloys is a critical metallographic tool in determining information about a sample. Understand the proportion and interaction between different phases in the microstructure that determine the performance and physical characteristics of alloys – these are automatically measured and reported using the ZEISS ZEN Multiphase light microscopy module.

Multiphase analysis segments your samples by their phase distribution at the click of a button. Phases are quantified on the basis of parameters you choose, such as size, shape or orientation and documented clearly in terms of their size, area percentage or in the form of a comparison – quickly, precisely, and reliably. For example, segregating magnesium disilicide or silicon in some aluminium alloys is critical to understanding and optimising their physical characteristics, as is determining the ferrite-pearlite ratio in structural steel.

Expand your horizons to multi-scale microscopy by using the multiphase module on your light microscope to assess phase composition.



Measurement of ferrite content in the vicinity of a weld in duplex stainless steel. Sample provided by TWI Ltd



Segregation of layers of high temperature corrosion scale on the surface of 9% Cr steel. Sample provided by TWI Ltd

Then perform a streamlined correlative analysis with a ZEISS electron microscope to gain further information about the chemistry and crystallography through EDS and EBSD, all from a single solution supplier and service provider to simplify your workflows.

ZEISS ZEN Intellesis provides an additional tool for the metallographer interested in multiphase analysis: a data-agnostic machine learning system that can be used alone or in conjunction with other software platforms.

Once trained on a small data set, ZEN Intellesis intelligently segments large sets of single or multichannel data generated using any microscopy method – light, electron, X-ray, EBSD, EDS, in 2D or 3D.

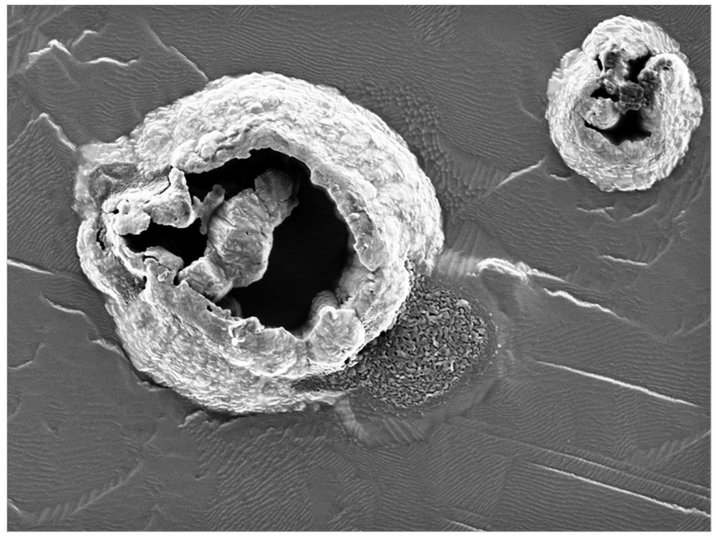
Routine Analysis Tasks
Non-metallic inclusions

The type and amount of non-metallic inclusions (NMI) in steels strongly affect the mechanical and physical properties of these steels.

Metallographic analysis of NMI is governed by industry standards that are fully supported by the modular and customizable ZEISS NMI software which guides the user quickly and easily through the workflow, generating a report and inclusion gallery fully compliant with the standards, or customer's own specifications.

ZEISS's NMI light microscopy module confirms that manufacturing processes, grade and quality of the product meet strict specifications for impurities or defects that can cause a component to fail or impact its tensile strength, toughness and fatigue.

Correlative solutions powered by ZEISS Shuttle & Find with ZEN Connect enable full chemical and crystallographic analysis of inclusions via energy dispersive X-ray spectroscopy (EDS) and electron backscatter diffraction (EBSD) in the ZEISS portfolio of electron microscopes.



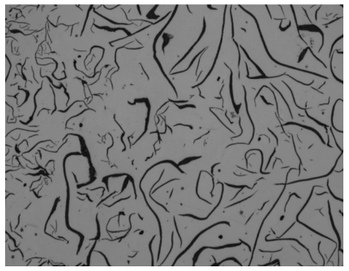
Inclusions in steel, taken using ZEISS Gemini FE-SEM with InLens detector at 1kV

Routine Analysis Tasks
Graphite in cast iron and other alloys

Identify, measure and characterize nodular, vermicular and spheroidal graphite in cast irons.

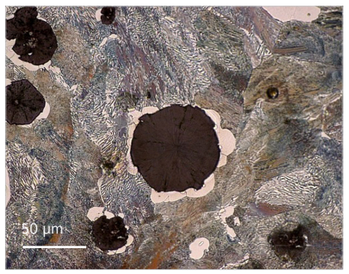
ZEISS light microscopes provide unsurpassed contrast modes and digital imaging and analysis capability for the routine quality engineer, or for the metals researcher. Characterizing graphite in cast iron by size and shape is achieved automatically by ZEISS ZEN Graphite module, according to EN ISO 945-1, as well as by spheroid number, or nodularity according to SAE J 1887.

Alternatively, graphite flakes in steel possess no structural integrity so can initiate crack formation. These can be identified and measured rapidly and in exceptional contrast. Uniquely, ZEISS light and electron microscopes can be used in correlative workflows to rapidly locate, measure, image and analyze these features and points of failure in multiple modes.

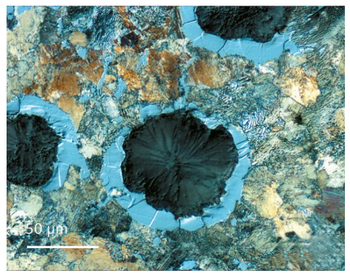


Flake graphite in cast iron.

Flake graphite in cast iron, etched sample
Images provided by University of Applied Sciences, Aalen, Germany



Spheroidal graphite in cast iron, taken in brightfield mode. Images provided by University of Applied Sciences, Aalen, Germany



Spheroidal graphite in cast iron, taken in CDIC mode
Images provided by University of Applied Sciences, Aalen, Germany

Routine Analysis Tasks
Layer thickness

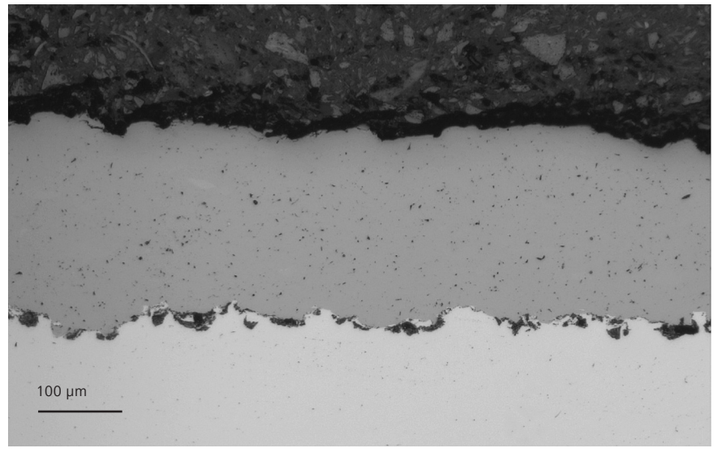
The engineering of multi-material coated, laminated, welded or fused components necessitates quantifying the thickness of the layers in your samples.

The ZEISS portfolio allows multiple options for you to characterise these layers. ZEISS ZEN Layer Thickness module provides an convenient assisted workflow, either in automatic or interactive mode.

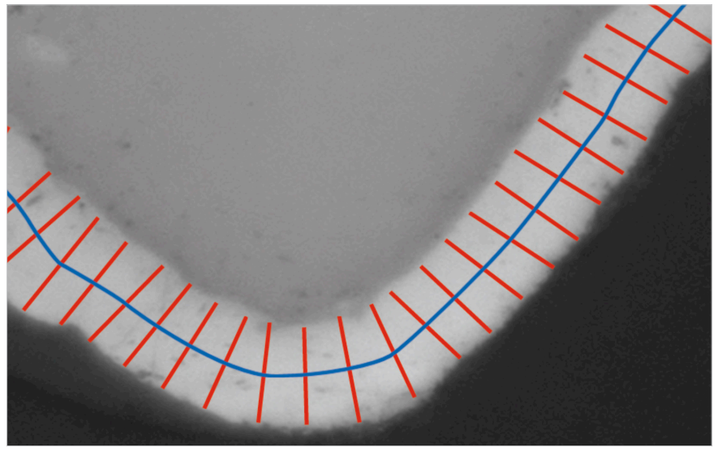
Layers can be identified by the software on the basis of their color or grayscale value, with measurement chords plotted at spacing of your choice, or drawn in interactively. ZEISS Layer Thickness then intelligently calculates the course of the chords, based on the layer gradient present.

Statistics of layer thickness can then be reported as maximum, minimum, mean, and standard deviation or exported for further analysis.

A distribution of the chord lengths can also be displayed graphically.



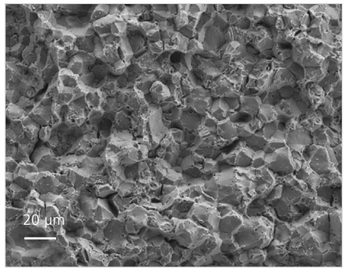
Cold-sprayed tantalum coating on 316 stainless steel. Sample provided by TWI Ltd



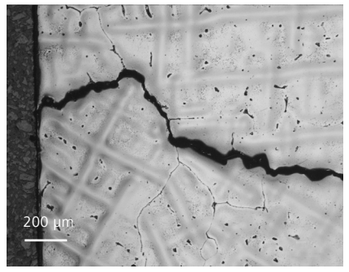
Layer thickness measurement on curved surface.

Broad Applications
Failure analysis

Finding the source of failure requires insight on the macro, micro and nano scales. Understanding the void, particle, inclusion, fatigue, grain or even crystal where a defect originated, or the failure properties of a metallic part, provides critical information to materials researchers, failure investigators and quality control analysts.

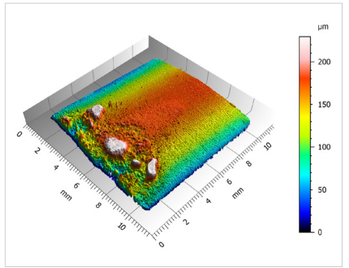


Brittle intergranular fracture surface.
Sample provided by The Test House, Cambridge

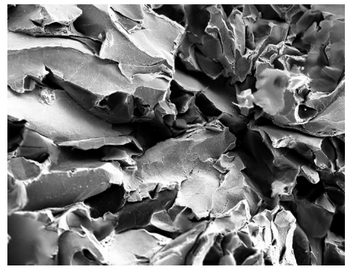


Cracking in nickel Alloy 825 casting.
Sample provided by TWI Ltd

ZEISS provides a portfolio of connected and correlated solutions for quantifying the chemistry, crystallography, topography and tomography of cracks, fissures and deformations in your metallic samples. Optical, electron and X-ray imaging, as well as energy dispersive X-ray spectroscopy, electron backscatter diffraction, focused ion beam milling techniques are all available including non-destructive largevolume techniques using X-ray microscopy. Software solutions are designed around the user to quickly generate actionable information, to solve and prevent recurrence of failures.



Profilometry of eroded electrical switch using ZEISS LSM 900 confocal microscope.



Steel fracture face after failure in tension.
Sample provided by The Test House, Cambridge

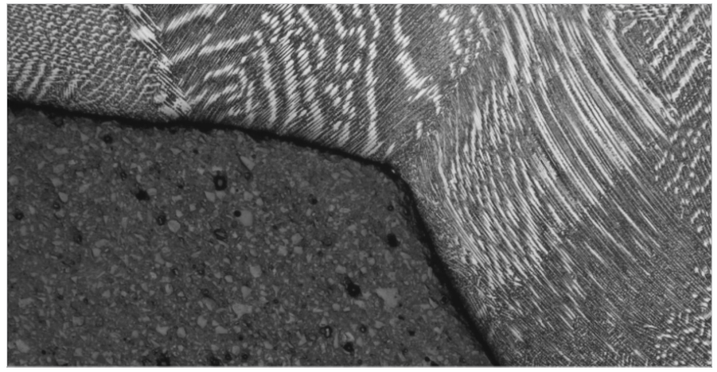
Rapidly locate, map and probe inclusions and fractures in 2D and 3D, or perform tensile testing with optional accessories for the electron or X-ray microscope. ZEISS MosaiX and ZEISS Atlas 5 software allow you to reconstruct, explore and connect analyses from different systems in a single interface, opening new possibilities for fast multiscale investigations of failures.

Broad Applications
Superalloys and other non-ferrous metals

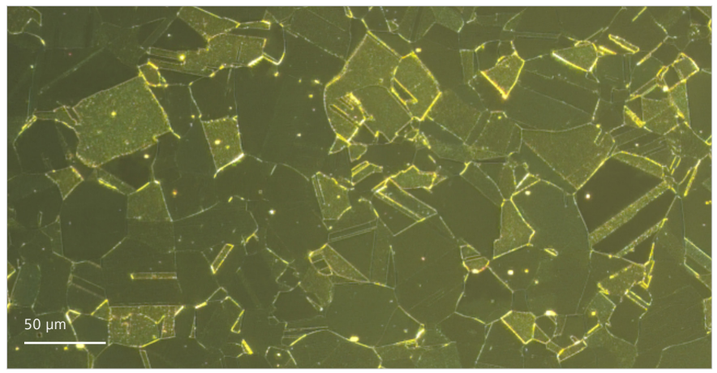
ZEISS solutions are available, tried and trusted, in a variety of advanced applications for characterization of metals and with demands on superalloys, aluminium and other light metals increasing, microscopy is able to provide new insights into the design and fabrication of novel materials.

Nickel-based super alloys have excellent mechanical strength, resistance to high temperature creep and corrosion. They consist of an engineered mixture of elements yielding an austenitic microstructure strengthened by intermetallic precipitates. Aluminum, titanium and magnesium alloys also play a vital role in automotive and aerospace industries, with their balance of low density, and mechanical performance fulfilling challenging service requirements. The ability to characterize chemistry, grains and assess the smallest of features is key to understand behavior in service.

Advanced metals and alloys can be microengineered with the knowledge ZEISS solutions provide for crystallography, elemental analysis, grain and phase analysis, physical and thermal testing as well as 3D imaging and inclusion analysis.



Root of nickel Alloy 625 weld, mounted in resin for analysis Sample provided by TWI Ltd



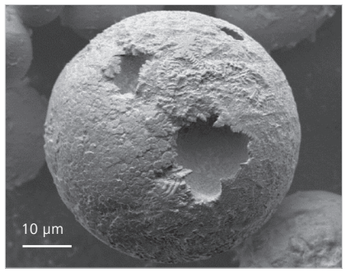
CZ106 / CW505L brass

Broad Applications
Roughness analysis

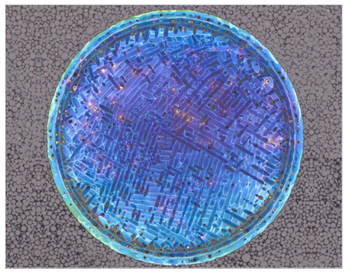
Additive manufacturing is changing the rules of metallurgy and of what it is possible to create in metals. New techniques mean new raw materials, alloys and analytical needs. The ZEISS family of microscopes is perfectly positioned to characterize new architectures and determine product quality in this developing field.

Microscopy can meet those needs in analyzing powder raw materials, assessing porosity and the effectiveness of the sintering process, in both two and three dimensions. Exploit surface and roughness analysis techniques, high resolution imaging of sintered and unsintered regions, and multiple imaging and contrast modes.

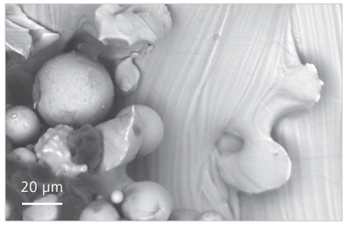
X-ray microscopy offers a unique capability to non-destructively assess porosity and 3D morphology of finished parts as a research or quality assurance tool, even for advanced, complex and critical printed parts.



Gas atomized ferro-cerium particle



Additively manufactured AlSi



Surface of additively manufactered titanium alloy component. Sample provided by TWI Ltd

3D scan of Al component produced by additive manufacturing and, inset, internal porosity imaged via X-ray microscopy

Broad Applications
Raw material analysis for steelmaking

Accurate characterization of incoming raw minerals enables maximum understanding of the coal, iron ore or sinter being fed to the blast furnace.

ZEISS brings its leading experience in automated mineralogy to the analysis of steelmaking raw materials, including iron ore, coal and coke. Ore and byproducts from non-ferrous metal production can also be quantified and reported on in considerable detail.

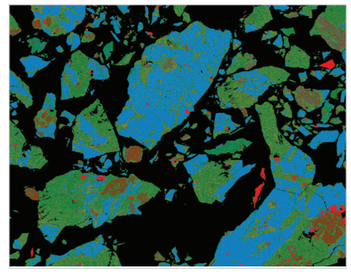
ZEISS Mineralogic combines a scanning electron microscope with one or more EDS detectors, a mineral analysis engine and dedicated software. Industry focused outputs can enhance extractive processes or the reduction-oxidation process in the blast furnace. Fast and accurate determination of the composition, grain size and mineral association and liberation in the feedstock, as well as understanding contaminants, can improve the efficiency and productivity of your process.

Slag, beneficiation agents and refractories also benefit from mineralogical analysis, as well as the full suite of ZEISS analysis products. ZEISS Mineralogic is already the leading mineral analysis software in the mining industry and can easily be deployed, bringing fast automated mineral analysis for maximum extraction efficiency.

Polarized light microscopy from ZEISS is also a vital tool in vitrinite reflectance analysis of coking coal for the blast furnace.

Stockpiles of iron ore. Photograph provided by the Materials Processing Institute, UK

Pushing the 350 Kg Pilot Coke Oven at the Materials Processing Institute, Middlesbrough, UK. Photograph provided by the Materials Processing Institute, UK.



Residual copper slag particle from large Zambian copper smelter, with phases classified using the Mineralogic system. Courtesy of Petrolab, UK

ZEISS Products for Steel and Other Metals

ZEISS Axio Imager 2
Tailored to demanding analysis tasks. Benefit from crisp images, high optical performance and an automated workflow.

ZEISS LSM 900
LSM 900 enables precise, three-dimensional imaging and analysis of metals and other materials. Combine all essential light microscopy contrasting techniques for materials with high precision topography.

ZEISS Axio Observer
Your open and flexible inverted microscope platform, offering all the capability, optics and imaging modes of the Axio Imager, with the capability to handle even large samples with easier sample preparation.

ZEISS Axioscope
The versatile modular microscope for routine metallography and research, offering flexibility, capability and economy, fully scalable through multiple configurations of stand, stage and illumination.

ZEISS Axio Vert.A1
The economical inverted microscope choice for rapid routine metallography and material analysis including large and heavy samples, with advanced contrast modes and automated workflows designed for repeatable routine tasks.

ZEISS EVO
The EVO family combines high performance scanning electron microscopy with an intuitive, user-friendly experience. EVO can be tailored precisely to your research and routine imaging and analysis requirements for metallic samples, welds, inclusions and failures.

ZEISS Sigma family
Your field emission SEMs for high quality imaging and advanced analytical microscopy. Accurate, reproducible and with an exceptional user experience, Sigma is the flexible and powerful workhorse SEM for routine, non-routine and metals research applications.

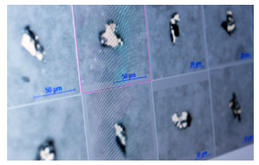
ZEISS GeminiSEM
Our flagship field emission system for the highest demands in metal characterization with sub nanometer resolution, high speed and surface sensitivity with ease of use and stability by design, making fast large area analytical microscopy possible, even at low kV.

ZEISS Crossbeam
High throughput 3D analysis and sample preparation tool, with integrated imaging and analytical solutions for understanding the 3D structure, chemistry, crystallography and structure of metals at the nano scale.

ZEISS Xradia Versa family
High resolution, non-destructive x-ray imaging of metallic samples, including additively manufactured and advanced microengineered parts, with intuitive navigation. Unlock crystallographic information in your lab with the optional LabDCT upgrade.

ZEISS Smartproof
Your integrated widefield confocal microscope for routine surface analysis: fast, precise, repeatable and robustly designed for industry. Roughness and topographical characterization is performed at high speed and resolution with included ConfoMap software for metrology.

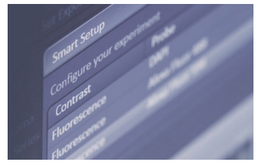
ZEISS Smartzoom 5
The award-winning smart digital microscope, ideal for quality control inspections and correlative microscopy. Focused on quick and easy setup and operate, it is designed for even novice users to produce excellent imaging.



ZEISS Shuttle & Find with ZEN Connect
Leverage the unique ZEISS multi-modal microscopy portfolio to bridge the micro and nano worlds with Shuttle & Find, a correlative microscopy interface for light and electron microscopes. A hardware and software solution allowing seamless transfer of your sample between microscopes in minutes, ZEN Connect and Shuttle & Find automates multiscale analysis of regions of interest.

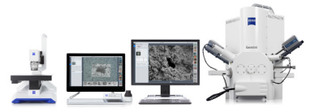
ZEISS Atlas 5

Correlative microscopy for multi-scale, multi-modal, multi-dimensional imaging and analysis. Blended learning workspace enables remote control of instruments and collaboration across geographies and imaging modalities.



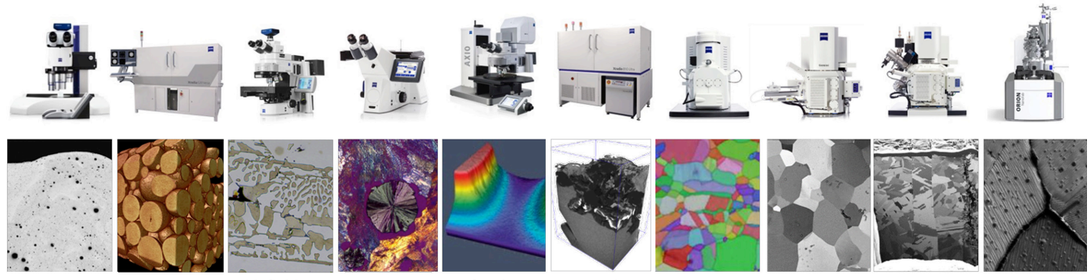
ZEISS ZEN Intellesis

Integrated, easy to use, powerful segmentation for 2D and 3D datasets available to the routine microscopy user.



ZEISS ZEN

ZEISS Efficient Navigation (ZEN) is the single user interface for almost all light microscopy imaging systems from ZEISS. Designed around usability, speed and GxP levels of auditability, the modular ZEN environment is designed around you and your needs.



Stereo LM | **Sub-micron XRM** | **Widefield Microscopes** | **Polarized LM** | **Confocal LM** | **Nanoscale XRM** | **C-SEM** | **FE-SEM** | **FIB-SEM** | **Helium Ion Microscope**

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