ChemiSEM Technology

SEM and EDS for materials characterization

thermo scientific

Insert chemistry into the heart of your SEM workflow

As materials research continues to advance, more and more researchers have begun using scanning electron microscopes (SEMs) for compositional analysis, and manufacturers have responded by equipping most SEMs with energy dispersive X-ray detectors (EDS). However, traditional EDS detectors are often purchased as separate systems, leaving some with disparate hardware and software solutions.

Thermo Scientific™ ChemiSEM™ Technology revolutionizes and simplifies EDS analysis by fully integrating SEM and EDS functions into a single, cohesive user interface. Based on live quantification and building on decades of expertise in EDS analysis, the technology provides elemental information quickly and easily, guaranteeing reliable results in less time ChemiSEM Technology now comes with a new powerfull feature: ChemiPhase. ChemiPhase identifies unique phases with a big data approach, finding minor and trace elements while eliminating user bias and reducing possible mistakes.

Benefits of ChemiSEM Technology

- **Always on**—Eliminate the need to move from SEM imaging to EDS analysis for each sample. ChemiSEM is always on and continuously collects the EDS signal during SEM imaging, collecting a full EDS spectrum at every point in the image.
- **Faster data acquisition**—Access elemental information much faster than conventional techniques with novel data segmentation approaches based on machine learning, ultrafast signal processing, and the tightest possible SEM EDS integration.
- **Reliable results**—Get accurate qualification and quantification over the widest range of operating conditions including beam energy, sample size, and working distance.
- **Complete information**—See the big picture with comprehensive micro-scale elemental composition. Immediate color results reveal defects or imperfections you might have otherwise missed.
- **Multi-data viewing**—See SEM imaging and elemental information in a single frame for complete characterization of your sample at a glance.
- **Simplified operation**—Immediately view compositional results that make elemental information accessible to everyone and easily increase the number of scientists or engineers who can use your facilities.

Using ChemiSEM Technology

A seamless SEM-EDS workflow

ChemiSEM Technology was built from the bottom up to provide full control over all SEM and EDS functions within a single user interface. Experiment setup, image processing, and spectral analysis functions are intuitively grouped, making data management straightforward. And the system features a quadrant format and project tree to highlight the most important data.

Interface functions:

A. View your sample

B. Switch between quantitative maps, count maps, and phase distribution maps

C. Generate a full-color overlay from any number of quantitative X-ray maps

D. Analyze any area of the ChemiSEM datacube using extract tools

E. Select and unselect elements of interest in the periodic table

F. Manage all data acquisitions in the project tree and easily generate reports

G. See either the atomic% or the weight% in quantitative maps

Figure 1. ChemiSEM user interface showing combined SEM-EDS operation in a single display.

Live chemical analysis

ChemiSEM Technology provides live compositional information during routine SEM navigation and imaging. Proprietary electron and X-ray data processing algorithms make ChemiSEM Technology incredibly fast. ChemiSEM works on a statistical basis, assigning segments, or superpixels, to the image which progressively shrink as data continues to arrive. This process ultimately converges on a pixel-precise EDS map, allowing the user to perform both rapid sample navigation and detailed quantitative analysis without switching setup parameters. For specimens where limited contrast is available in the SE or BSE images, ChemiSEM Technology enables users to switch to traditional square pixels to provide full flexibility of analysis.

ChemiSEM Technology also allows for on-the-fly visualization of the elemental concentration at each point thanks to the tooltip function.

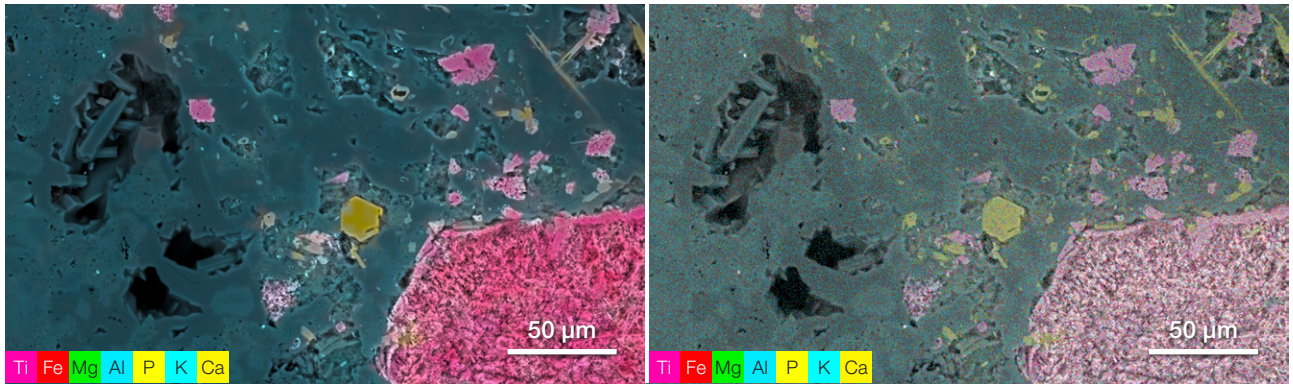


Figure 2. ChemiSEM image (left) and gross counts mapping (right) of contaminants on a battery anode.

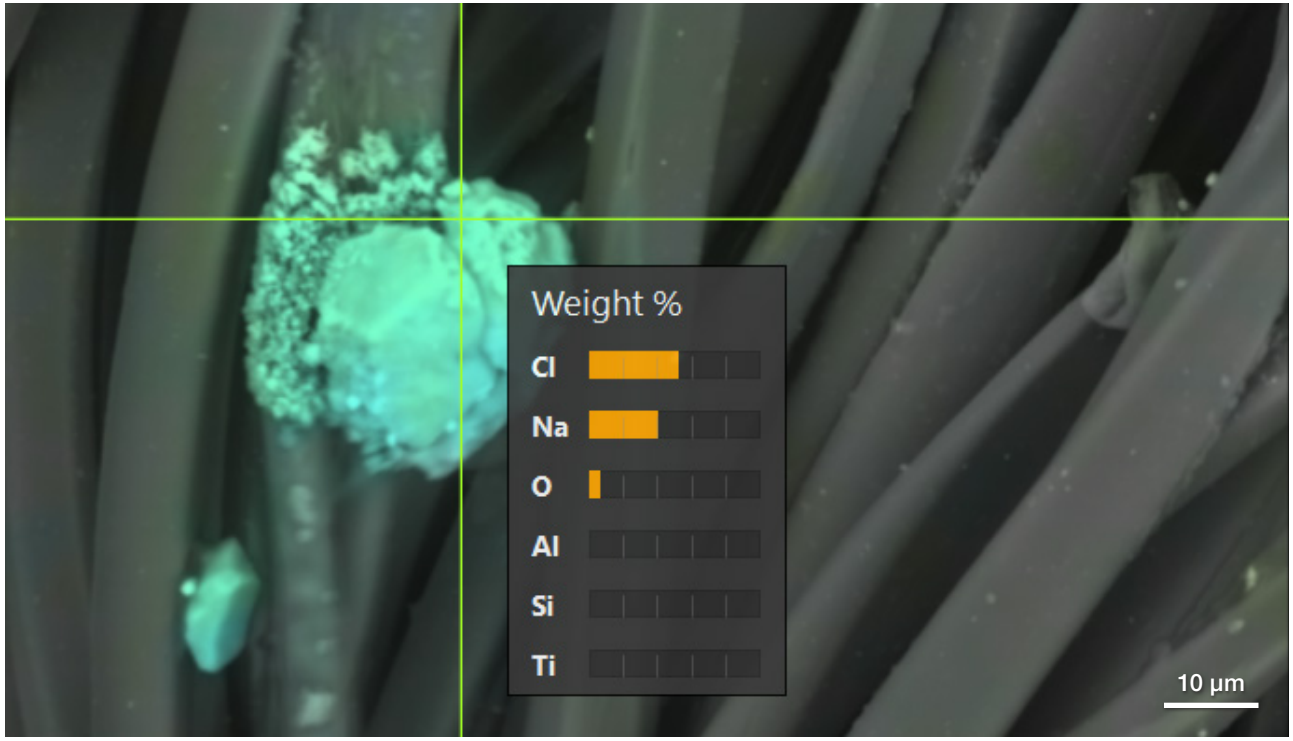


Figure 3. Live view of the SEM user interface showing a ChemiSEM image of unknown materials on a used face mask. The tooltip shows the composition of one of the regions, making it easily identifiable as sodium chloride, hence not a harmful contaminant.

Large area montage

Thanks to its full integration in the SEM user interface, ChemiSEM Technology can help you acquire large-scale images. Such overviews are available through the native image montage creation, which automates acquisition over large areas.

Navigation montage automatically collects multiple neighboring images while collecting the EDS signal for each frame. The EDS signal is then processed to provide quantitative information, and the resulting low-magnification images provide a large-scale overview of the sample in a short period of time.

Navigation montage can be used as an effective screening tool to identify features of interest for further in-depth analyses.

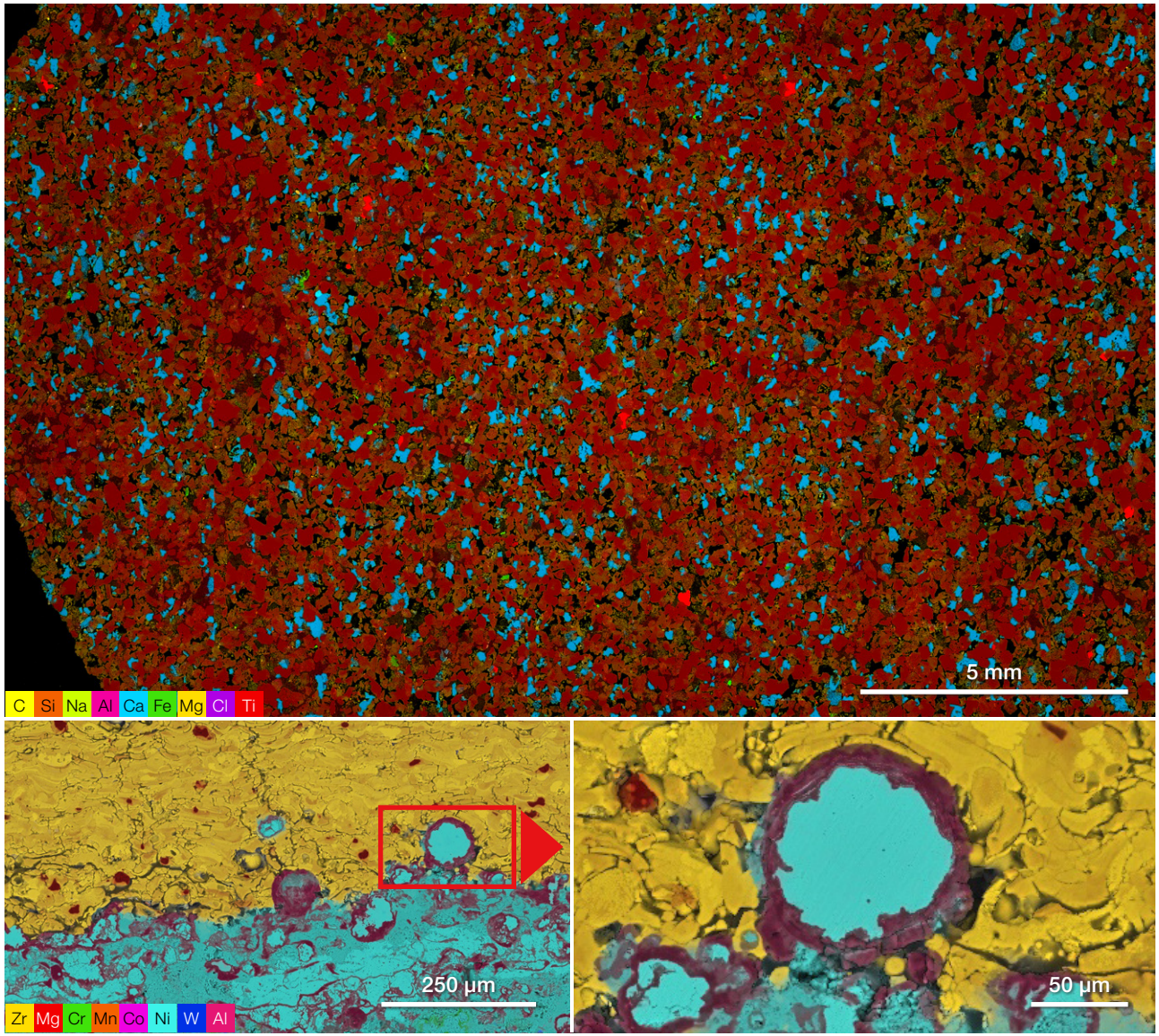


Figure 4. Examples of navigation montages acquired from a large area (FOV of about 20 mm) of a geological section (top) and a cross section of a heavily cycled thermal barrier coating (TBC) (bottom). The TBC overview clearly shows different layers, with the Ni-based superalloy on the bottom passing through the bond coat and top coat. The contribution of the EDS signal to such a large-scale overview highlights the presence of an inhomogeneous interface between the layers and their different arrangement, which, due to the extensive use of the material, differs from the as-manufactured system. Thanks to the combination of ChemiSEM Technology and navigation montage, the user can easily and quickly navigate directly to the area of interest for higher magnification and more detailed analyses.

Quantitative analysis

ChemiSEM Technology incorporates innovative algorithmic approaches, smart spectral fitting, and optimized matrix correction routines to facilitate accurate and precise quantification, even in the presence of multiple overlapping elements.

Spectrum Clean

ChemiSEM Spectrum Clean removes sum and escape peak artifacts when two X-ray beams arrive near simultaneously and are detected as a single event. Because their occurrence is on a statistical basis, they are more prevalent at higher count rates. On other systems, the sum peak removal processes can fail, particularly for complex material types. New ChemiSEM sum peak removal works on energy deconvolution and is entirely independent of the auto ID algorithm.

Peak identification

ChemiSEM Technology uses an iterative auto peak ID with adaptive digital filtering for background removal and linear least-squares fitting to resolve overlapping peaks. As more data arrives, results are continually modeled and refined using a range of statistical validation routines, providing complete confidence in your results. You can also predefine included, excluded, and absented elements for faster analysis of known materials.

Quantification

ChemiSEM PROZA Phi-Rho-Z matrix corrections deliver improved accuracy for light element analysis. Quantification can be provided live or from any spectrum as post processing for added flexibility. You can select KLM lines for quantitative analysis either automatically or manually.

Element	Limiting chemical composition	Measured values with 1.2 nA beam current		Measured values with 4.5 nA beam current	
	Percentage	**Average**	**STD DEV**	**Average**	**STD DEV**
Ni	50-55%	52.975	0.404	52.915	0.329
Cr	17-21%	20.095	0.354	19.925	0.579
Nb	4.75-5.5%	5.39	0.597	5.995	0.952
Mo	2.8-3.3%	3.215	0.057	3.315	0.057
Ti	0.65-1.15%	0.92	0.108	0.915	0.073
Al	0.2-0.8%	0.505	0.038	0.495	0.022
Co	Max 1%	0.09	0.062	0.16	0.092
Si	Max 0.35%	0.1	0	0.1	0
Mn	Max 0.35%	0.175	0.07	0.32	0.04
Fe	Balance	16.58	0.5	16.6	0.5

Figure 5. Quantitative analysis of an Inconel 718 reference material acquired with 20 measurements per sample, an accelerating voltage of 20 keV.

Spectrum simulation

Spectrum simulation automatically validates elemental identification and quantification based on your exact microscope settings, providing total confidence in your analytical results. Background and synthetic spectra consider your exact accelerating voltage, working distance, and beam current and can be run live or to any previously acquired spectrum.

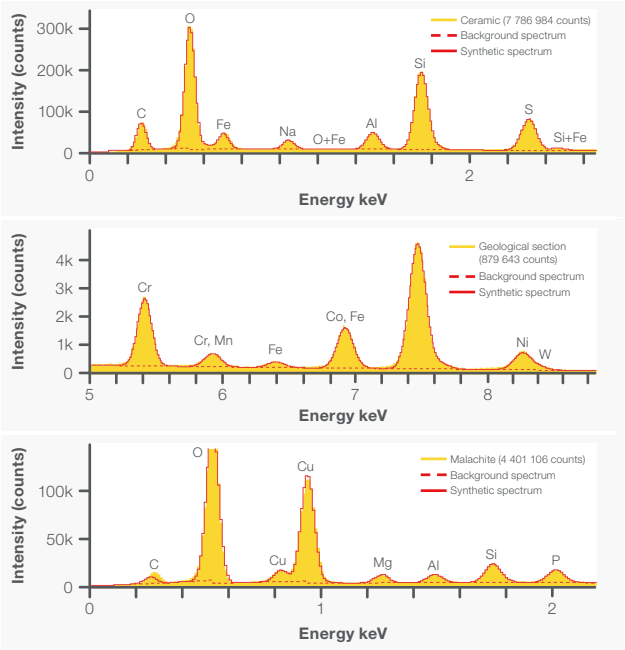


Figure 6. Examples of spectra acquired from a ceramic (top), a geological section (middle), and a polished section of malachite (bottom) under different acquisition conditions. In all cases, both background (dotted line) and synthetic spectrum (red line) can be seen. The ways in which simulated spectra fit with experimental data are clearly visible regardless of the acquisition condition and material, confirming the high quality of the processing.

Compound analysis

ChemiSEM Technology supports analysis of compounds by stoichiometry for a complete sample picture. Analyses of borides, oxides, carbides, and nitrides are supported.

Element	Line	Formula	Compound %	No. of Cations	At. %	Wt. %
O	K				60.0 %	26.2%
Ti	K	TiO_2	43.6 %	1.00	20.0 %	26.1%
Sr	L	SrO	56.4 %	1.00	20.0 %	47.7 %
				2.00		

Figure 7. Analysis of compounds obtained from a tausonite sample using ChemiSEM Technology. Quantification and stoichiometry confirm the software's accuracy, as can be seen in the nominal weight percentages (26.16% O, 26.09% Ti, 47.75% Sr) and nominal compound percentages (43.53% $Ti0_2$, 56.47% SrO).

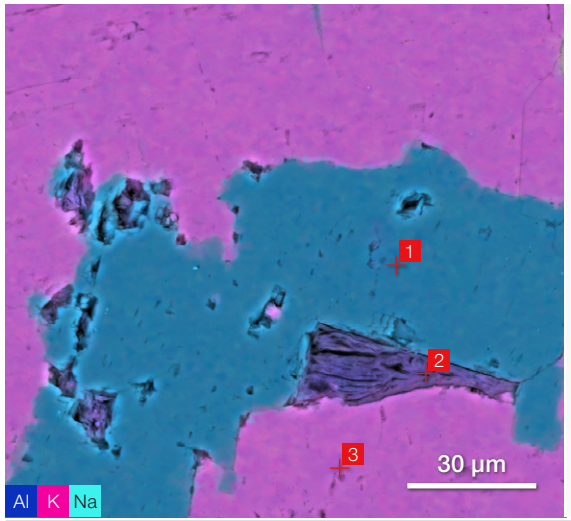
Modes of analysis

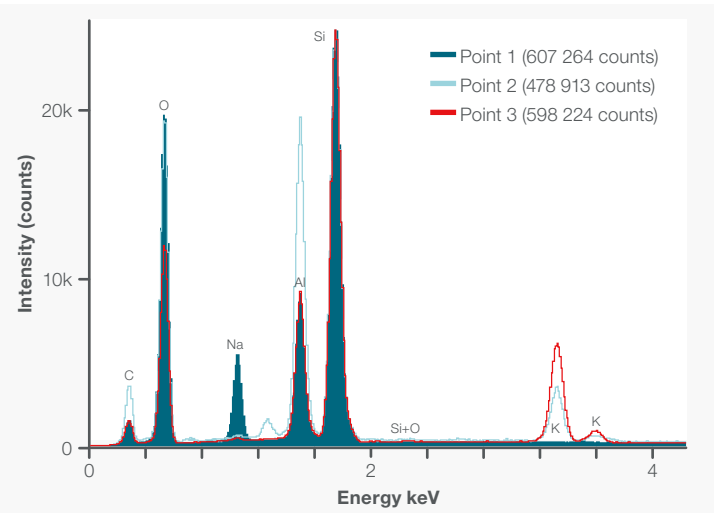
ChemiSEM Technology enables easy switching between point mode, linescan, and X-ray mapping to help you better understand the specimen story.

Point analysis mode

Full elemental information at any point or region on the electron image:

- Define and analyze any area in the electron image, from a single point to larger areas
- Analyze regions instantly using a survey mode or toggle to a sequenced acquisition for an unlimited number of points or areas
- Easily overlay a point's spectrum to compare different areas
- Save acquisition parameters (time or number of counts) as presets
- See the elemental analysis of each selected area in a comprehensive data table





Element	Atomic % point 1	Atomic % point 2	Atomic % point 3
C	13.2	22.2	13.7
O	55.8	52.4	54.3
Na	6.4	0.2	0.3
Al	6.2	9.2	6.5
Si	18.4	13.9	19.1
K	0.0	2.2	6.0

Figure 8. Sandstone cross section. Point analyses can be run on any point through the main imaging window. Spectra are easily overlaid to display compositional differences. Spectra and point quantification are displayed in a single workspace.

Linescan mode

Chart compositional changes across your sample:

- Seamlessly switch between net counts, atomic%, and weight%
- Easily overlay different linescans to compare different areas and obtain elemental ratios
- Save acquisition parameters (time, number of counts, or number of points) as presets in the user interface
- Choose between single or multiple passes over the line

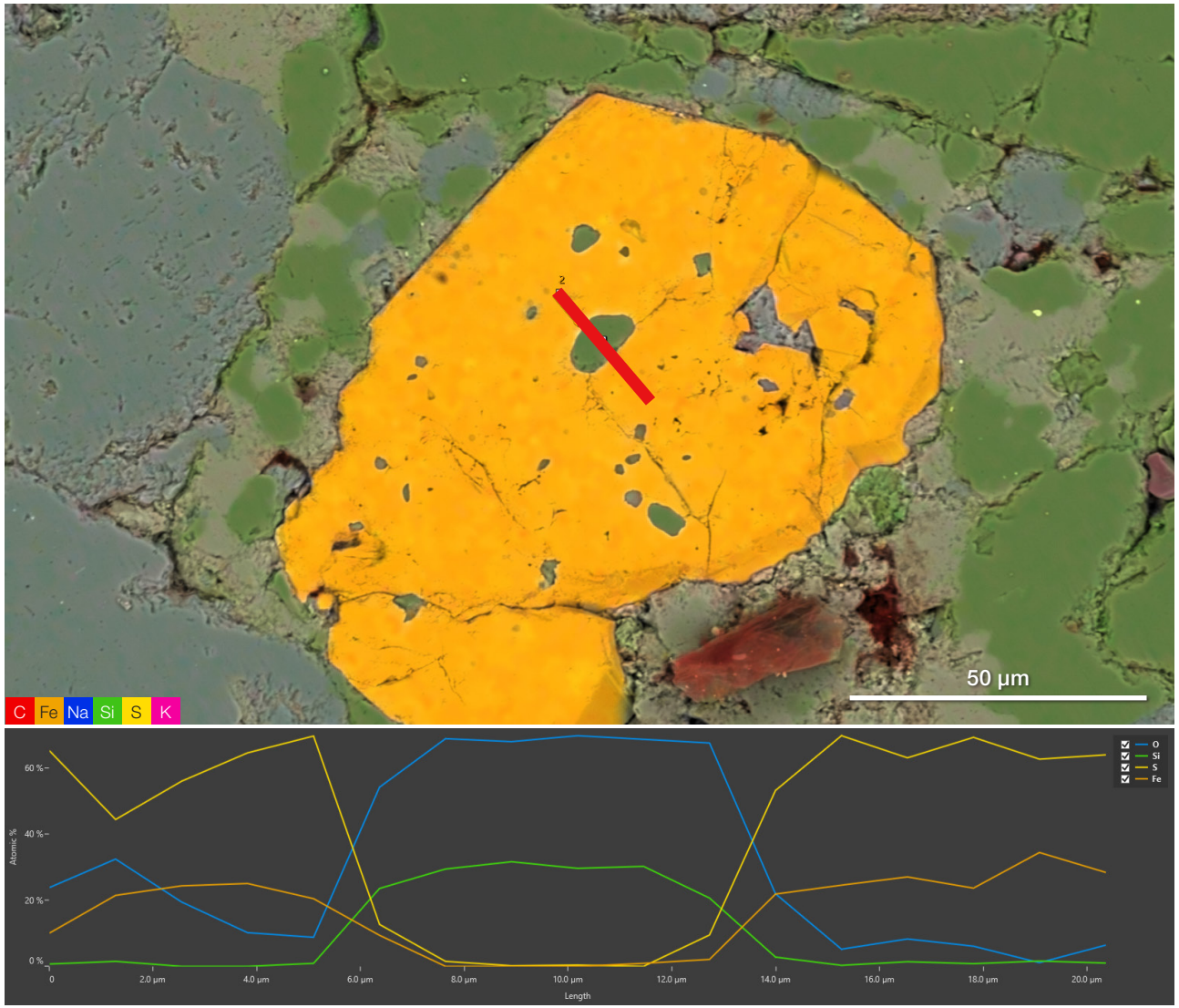


Figure 9. Geological cross section showing a silica particle within an iron sulfide cluster. The definition of parameters, acquisition of the line, and visualization of the elements and elemental profiles are all integrated in the same user interface and immediately available during sample navigation.

Mapping

X-ray maps are available both live during the acquisition and offline after the acquisition is completed. ChemiSEM Technology stores a spectrum at every pixel, yielding data that can be analyzed repeatedly without the need to re-acquire or re-create acquisition parameters.

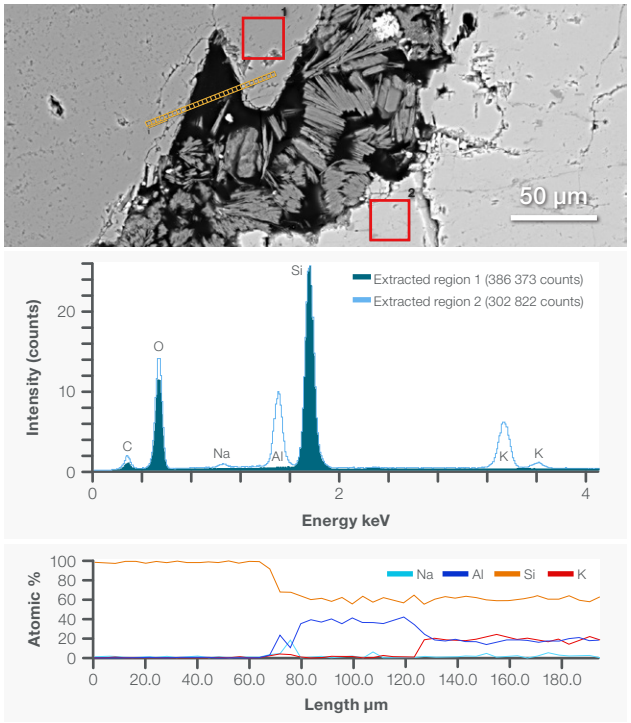


Figure 10. Sandstone cross section. Extracting the spectrum and quantification from different areas allows you to quantify compositional differences easily and quickly.

Live peak deconvolution

ChemiSEM maps include a sophisticated background removal algorithm. Any peak overlaps are deconvoluted and assigned using least squares fitting based on a library of peak shapes. In the net counts realm, ChemiSEM Quantitative Mapping makes evaluating complex sample compositions effortless, delivering accurate elemental analysis.

With conventional mapping, the signal from one peak may be assigned to two elements, generating an error in the distribution of elements (Figure 12, bottom). ChemiSEM Quantitative Mapping, on the other hand, automatically deconvolves peak overlaps and correctly assigns them to the correct elements (Figure 12, top).

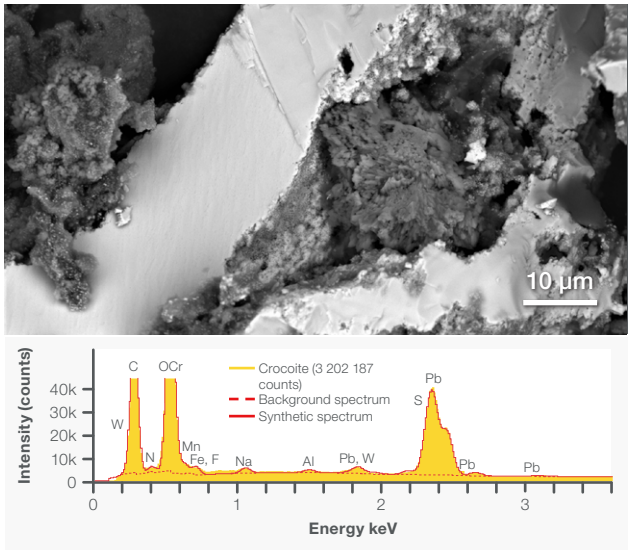


Figure 11. Crocoite mineral, a Pb-rich material, with soil. The spectrum shows the overlap between Pb and S (S k_α energy line is at 2.307 keV while Pb M_α energy line is at 2.346 keV).

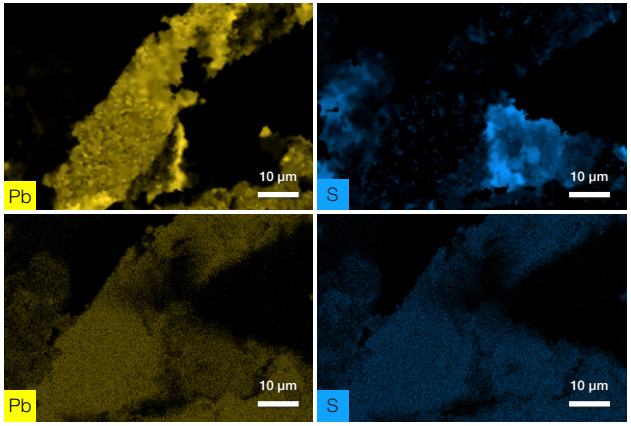


Figure 12. ChemiSEM Quantitative Maps (top) and conventional gross counts maps (bottom). Both conventional gross count maps are based on a signal coming from one peak and are therefore the same.

With ChemiSEM Quantitative Mapping, you can:

- Map the distribution of elements or phases across the sample surface
- Acquire fully deadtime-corrected quantitative mapping, incorporating background removal, deconvolution of peak overlaps, and matrix correction during acquisition
- Maintain image stability with advanced drift correction routines

ChemiPhase

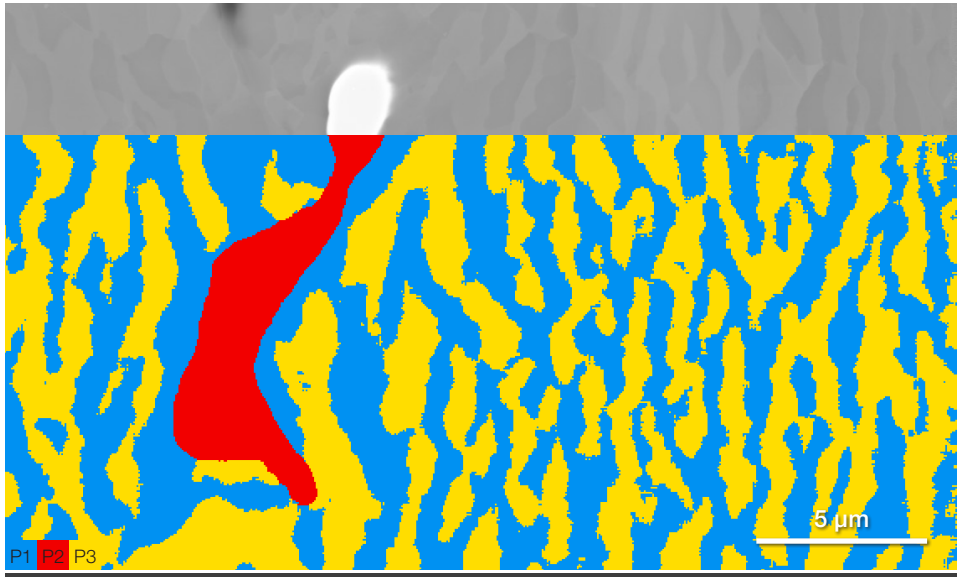
Identify unique phases using advanced statistical analysis

ChemiPhase uses a big data approach to detect all statistically significant spectra within the datacube. It provides a simple probability that each pixel belongs to each detected significant spectra. This makes interpretation of complex samples much more straightforward and intuitive because each pixel can only belong to a single phase.

ChemiPhase is a comprehensive, unbiased statistical engine. This avoids problems with traditional methods, which often yield erroneous results if unexpected elements are missed due to overlapping peaks or insufficient intensities. Traditional phase determination is highly dependent on assumptions about the sample.

Benefits of ChemiPhase

- No user bias
  - Run the fully automated process with no prior identification of elements
  - Locate minor and trace elements without extensive experience
- Complete and comprehensive analysis
  - Unambiguously identify major and minor components down to a single pixel
  - Locate unique components where peak overlaps obscure significant elements
- Fast acquisition
  - Start phase determination with very little X-ray data—as few as 10 counts per pixel
  - Complete most acquisitions in less than a minute, even for complex phase maps
- Reduced complexity
  - View a simple image-spectrum pair for each distinct phase
  - Automatically optimize all spectra for a more confident analysis



Element	Ni	Co	Cr	W	Ta	Al	Re
wt.% γ'	66.4	6.8	4.9	4.6	8.2	6.6	1.2.
wt.% γ	58.9	9.4	9.6	7	3.8	4.4	4.7.

Figure 13. ChemiSEM phase identification in a Rene N5 Ni-based superalloy. The image shows a tantalum carbide in the base alloy, which is made of two phases: gamma (blue) and gamma prime (yellow). ChemiSEM quantification of each of the phases was calculated from only 30 average counts per pixel, as shown in the extracted point spectrum from the gamma phase.

Drift correction

Automatically track features and keep the image correctly positioned throughout data acquisition

Acquisitions taken over long periods of time or at high magnification may be susceptible to sample movement, producing blurred X-ray maps and inaccurate quantification.

ChemiSEM Drift Compensation Software systematically monitors sample position and adjusts for sample drift, enabling higher magnification operation and longer acquisition times.

- Based on Drift Compensated Frame Integration (DCFI) algorithm, which is used across Thermo Scientific SEMs and TEMs
- Shortest dwell time EDS drift correction—works in as little as 200 ns
- Simple operation in the microscope control platform

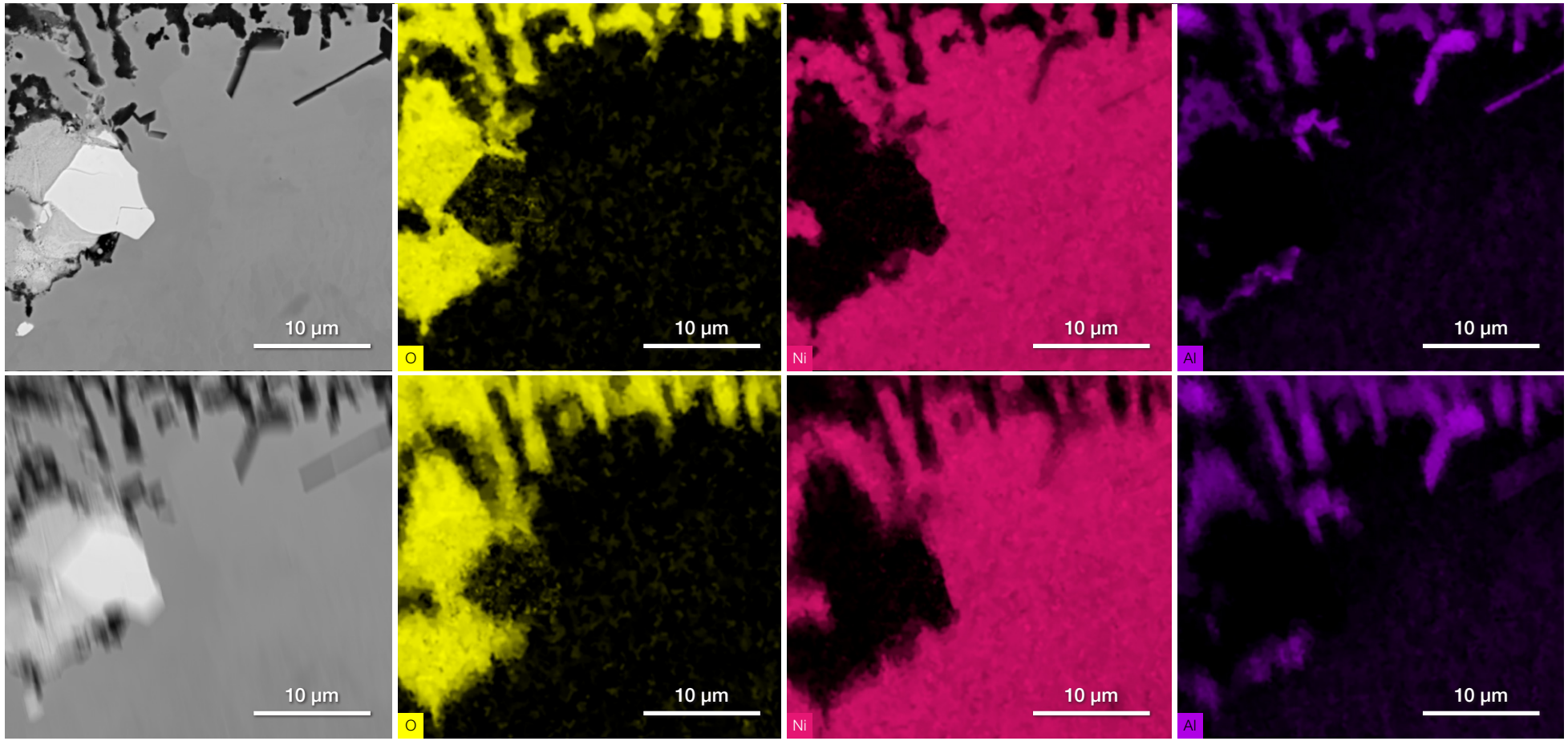


Figure 14. Rene N5 superalloy cross section showing surface damage and oxidation from thermal cycling. Top: drift corrected. Bottom: no drift correction.

ChemiView Software

Boost productivity with complete and comprehensive offline analysis

ChemiView Software offers full offline data processing and reporting functionality to help you take—and analyze—your data anywhere.

Each session can be saved and exported for post processing on any device. After importing each data cube, a wide range of options and features help you re-elaborate data, adjust colors, extract spectra from smaller areas, or simply cross-check analyses with previously acquired data. The reporting function allows you to easily save selected data in a customized report.

ChemiSEM, ChemiSEM Advanced, and ChemiVIEW on Thermo Scientific™ Axia™ and Apreo™ 2 Microscopes are commercially available as a one-time purchase or may be included in your value-added service contract.

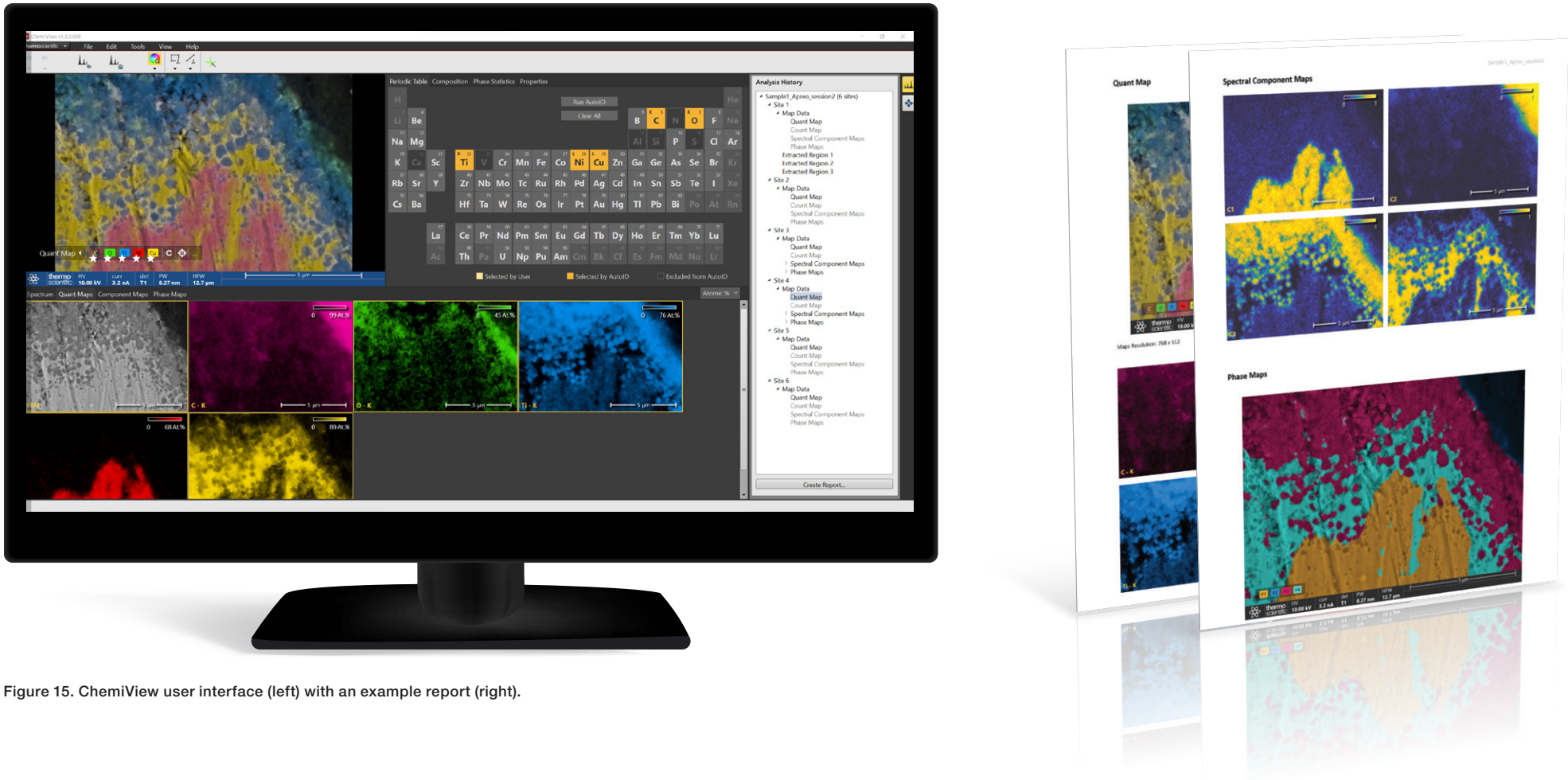


Figure 15. ChemiView user interface (left) with an example report (right).

Feature	ChemiSEM	ChemiSEM Advanced	ChemiView
Full integration of all SEM EDS functions in a single user interface	●	●	n.a.
Project-based data storage	●	●	●
Project data tree for easy data management	●	●	●
Industry-standard data formats	●	●	●
Dedicated analytical mode with seamless data blending between point, line, and mapping modes	●	●	●
Choice of any electron image type available in the xT SEM user interface	●	●	●
Single-click reporting	●	●	●
Sum peak removal	●	●	●
Escape peak removal	●	●	●
Spectral terminations based on time or statistics	●	●	●
Automatic peak identification	●	●	●
Synthetic and background spectral overlays	●	●	●
Accurate quantification over a wide range of working distances, beam currents, and beam energies	●	●	●
User-definable selections for included, excluded, or absent elements	●	●	●
Automatic or user-defined KLM line selection for quantitative analysis	●	●	●
Background removal by digital filtering	●	●	●
Standardless quantitative analysis using filtered least squared fitting	●	●	●
Quantification using PROZA matrix correction for superior light element performance	●	●	●
Qualitative and quantitative linescans with termination by time or statistics	●	●	●
ChemiSEM Technology using electron image processing for accelerated quant mapping	●	●	●
Always-on live quantitative mapping with fully deconvolved X-ray maps	●	●	●
Gross count mapping with per-element line selection	●	●	●
Optional quantitative mapping using square kernelization	●	●	●
Overlay of all map types onto the electron image	●	●	●
Map termination based on time or statistics	●	●	●
User-definable or auto-generated elemental color selection	●	●	●
Navigation montage to acquire and stitch multiple frames	●	●	●
Spectral extractions using point and rectangle	●	●	●
Linescan extract from X-ray maps with flexible line direction, width, and point selection	●	●	●
Normalization for comparison of multiple spectra		●	●
Display of individual quant maps		●	●
Drift compensation mapping based on DCFI		●	n.a
Compound analysis of borides, carbides, oxides, and nitrides by stoichiometry		●	●
ChemiPhase		●	●

Patents pending (US 16/941,253; US 16/867,770; US 16/867,972; US 16/886,716); Patents granted (US 11,002,692 B1; US 8,748,816 B1; EP 2546638 B1 ; US 11,327,032 B1)

Support for every possible need

NanoPorts

Thermo Fisher Scientific supports you at the early stage with demonstrations and application support. The teams at our five NanoPorts can define solutions tailored to your application needs and provide dedicated on-site or remote demonstrations. In addition to acting as research collaboration centers, our NanoPorts give full support to our R&D, factory, and field service teams, helping to provide optimized outcomes and improved solutions.

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Our global service logistics network includes warehouses, regional hubs, and local stock locations to ensure that you receive the best customer service. From installation services to on-site and remote maintenance, our team of experts is here to support you at every step.

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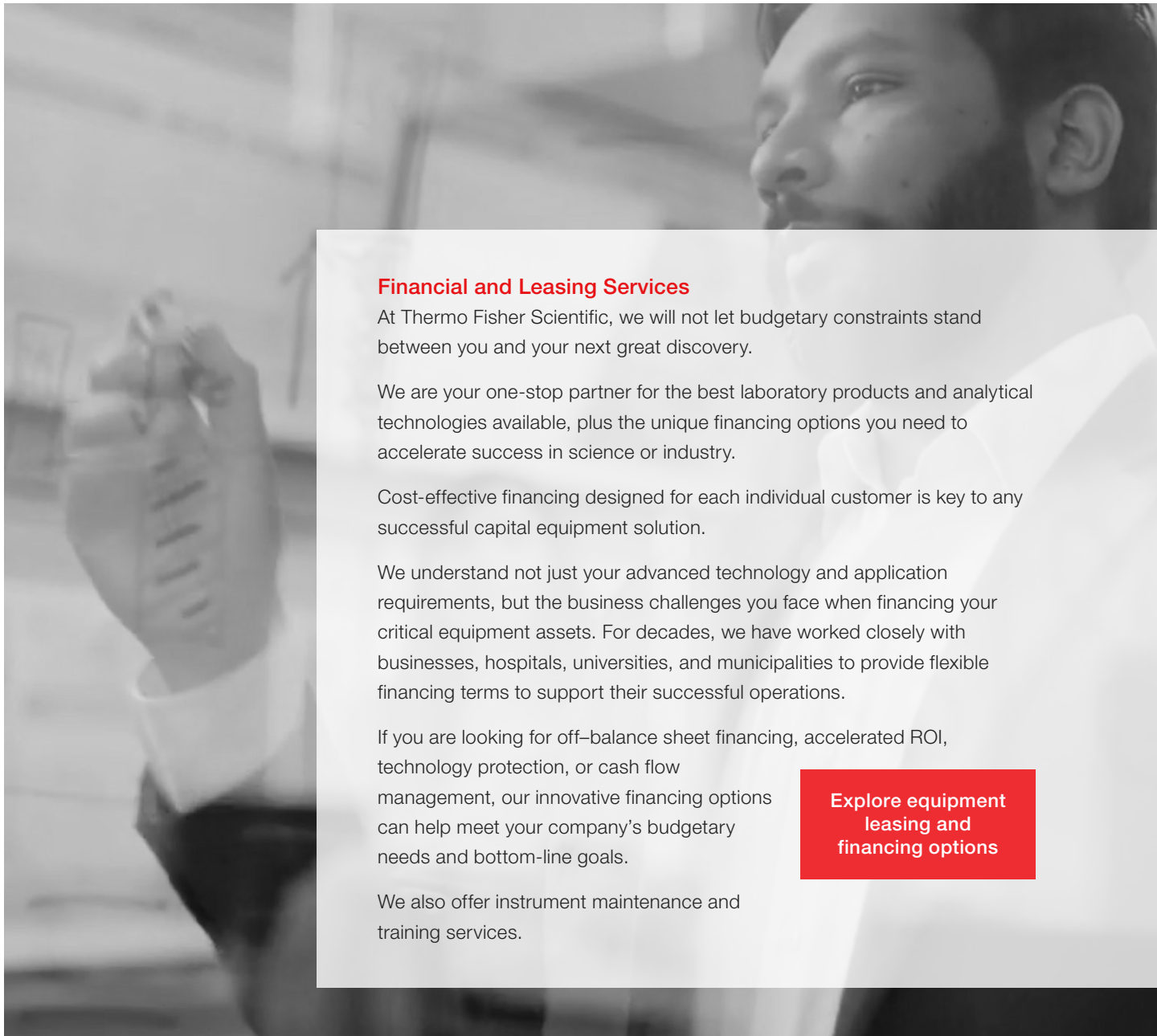
With the My Microscope tool, we can quickly respond to issues with your instrument throughout its entire lifespan. Plus, the tool automatically updates the user interface to help you get the most out of your investment.

About Thermo Fisher Scientific

We are the world leader in serving science. Our Mission is to enable our customers to make the world healthier, cleaner and safer.

Step ahead. Step beyond. Duration 1:33

Our innovative solutions for electron microscopy, surface analysis, and microanalysis help materials science researchers advance their sample characterization to gain deeper insight into the physical and chemical properties of materials from the macroscale to the nanoscale. Our multiscale, multimodal solutions cover a broad range of applications across dozens of industries and research fields, serving customers in academia, government, and industry. Our TEMs, DualBeam™ FIB-SEMs, comprehensive portfolio of SEMs, XPS, and microanalysis solutions, combined with software suites, take customers from questions to usable data by combining high-resolution imaging with physical, chemical, elemental, mechanical, and electrical analysis across scales and modes.



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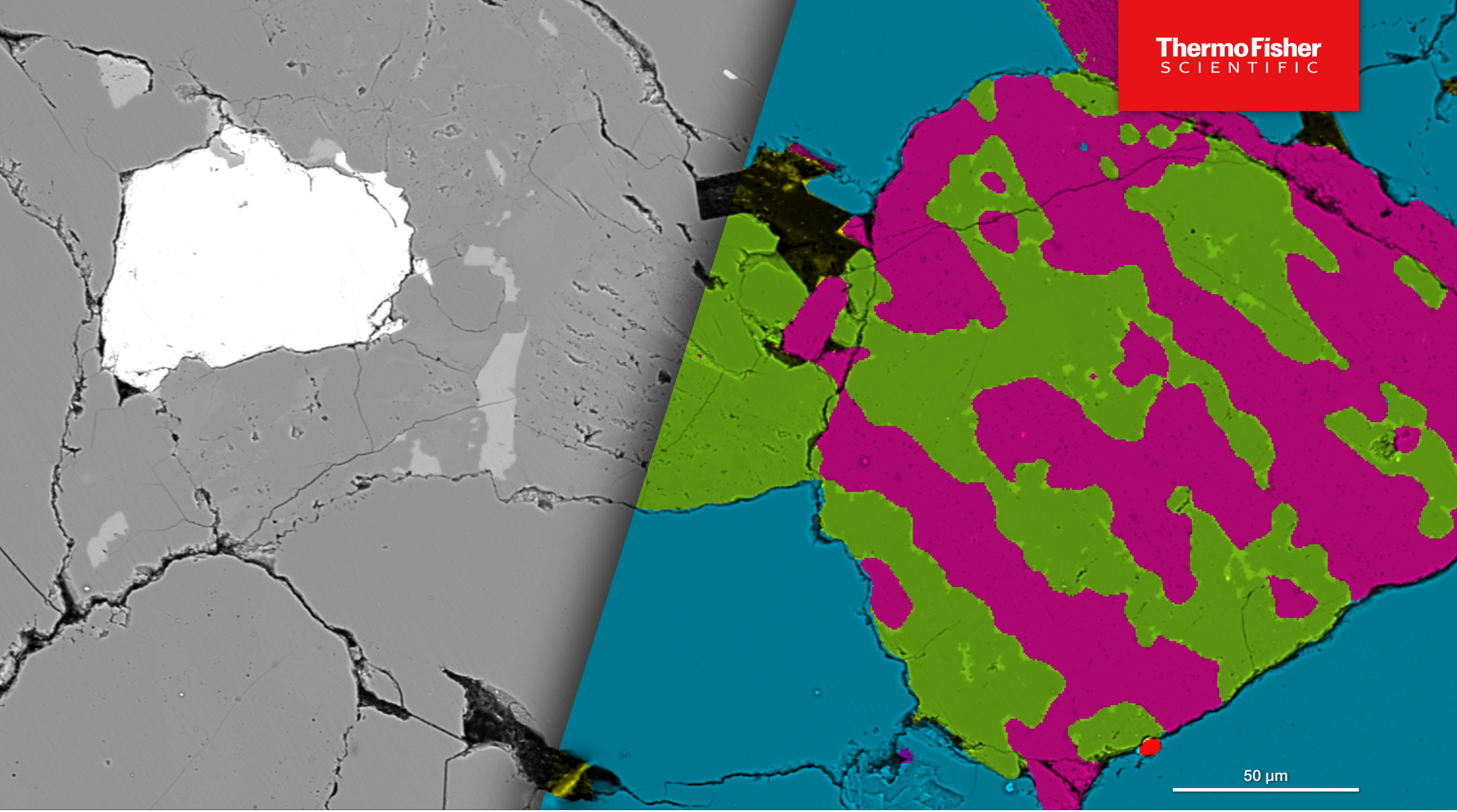

Geological section characterized using ChemiSEM phase analysis.

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

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