MICRO-XRF

M4 TORNADO

High Performance Micro-XRF Spectrometer

Innovation with Integrity

M4 TORNADO – The Standard in Micro-XRF

Micro-XRF is the method of choice for highly sensitive and non-destructive elemental analysis of diverse samples, including inhomogeneous and irregularly shaped specimens. The M4 TORNADO is a versatile instrument for fast and accurate high-resolution analysis of both small and large specimens. Samples require little or even no preparation at all for examination.

Features

- Excellent spatial resolution using polycapillary X-ray optics for smallest spot sizes < 20 µm for Mo Kα
- Flexible excitation through use of up to two X-ray tubes with HV steps of 1 kV and 8 filters
- Ultra fast spectrum acquisition with XFlash® SDD technology
- Additional speed and information through and optional second spectrometer
- TurboSpeed X-Y-Z stage for distribution analysis on the fly
- Sample positioning supported by simultaneous display of two sample images in different magnificactions
- Vacuum sample chamber for optimized light element performance
- EasyLoad function for fast and convenient sample exchange and high-performance vacuum pump
- Quantification of bulk material using a standardless FP model

Benefits

- Resolve small details while maintaining an unmatched X-ray flux
- Adapt the excitation perfectly to your sample
- Increase measurement speed with up to 275 kcps throughput per spectrometer
- Double the count rate in any measurement mode
- Record element mappings more quickly with most spectral information collected for any step size
- Position samples precisely under the X-ray spot and acquire high-resolution images of sample features
- Quantify from Na to Am with low limits of detection
- Prepare samples outside of the chamber and start measurements in less than three minutes after insertion
- Adapt the robust and reliable quantification routine for maximum accuracy

Instrument Highlights

Efficient sample excitation

The use of polycapillary X-ray optics enables the generation of high fluorescence intensities even on smallest sample areas. The X-ray optics allow focussing the tube radiation from a large solid angle and concentrate it on spots < 20 µm for Mo Kα radiation.

The optional use of two X-ray tubes permits very effective excitation of specific elements by selecting different target materials and by using one tube with a collimator for high-energy excitation.

Fast spectrum acquisition

The M4 TORNADO is equipped with Bruker's XFlash® silicon drift detector (SDD) technology. This ensures an energy resolution < 145 eV at Mn Kα with input count rates > 300 kcps for a single detector setup.

An optional second SDD speeds up data acquisition by a factor of two and optional 60 mm^2 area detectors allow the collection of radiation from a larger solid angle.

TurboSpeed stage

The large sample stage travels at a maximum speed of up to 100 mm/s. In combination with the "on the fly" measurement mode, this ensures the fastest possible mapping with minimal loss of spectral information, as the detector continuously collects spectral information.

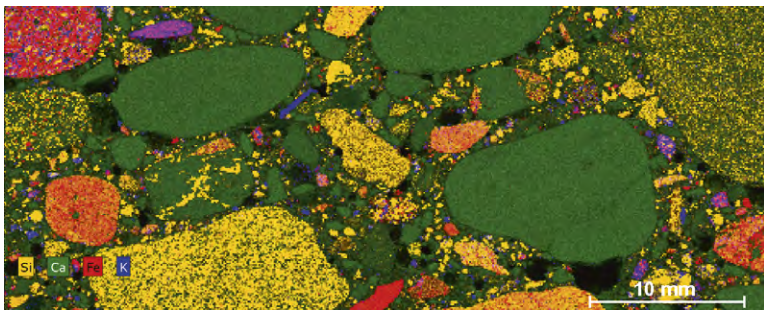
Information about the element distribution can be obtained with an acquisition time of < 1 ms per pixel. This allows obtaining an overview of the sample composition within minutes. Due to the high precision of the TurboSpeed stage, multi-frame measurements can be routinely performed for refined analysis. Longer acquisition times provide even more analytical details.

Convenience and ease of use

- EasyLoad function for fast sample exchange
- Large sample chamber that enables a stage travel of 200 x 160 x 120 mm^3
- Sample positioning supported by a fisheye camera and two optical video microscopes displaying approx. 1 mm^2 and 10 mm^2
- Auto focus function for correct sample height adjustment
- Stitching of high-quality mosaic images for large-area maps
- Distribution analysis with HyperMap technology to collect and store complete data sets for offline analysis and data mining.

Accurate and flexible quantification

Since samples are often inhomogeneous in the volume under the X-ray spot, the M4 TORNADO relies on standardless analysis using fundamental parameter (FP) models. Based on such an FP model, the Bruker software module M-Quant provides reliable results on the composition of bulk samples.



Fast mapping of a concrete sample
Dwell time 1 ms per pixel, 100 k single spectra in 10 min total scan time.

Applications

The M4 TORNADO is an extremely versatile instrument. The main applications are in materials science, forensics, geology, RoHS measurements, archaeometry and life sciences. Many other applications are also supported.

Forensics and archaeometry

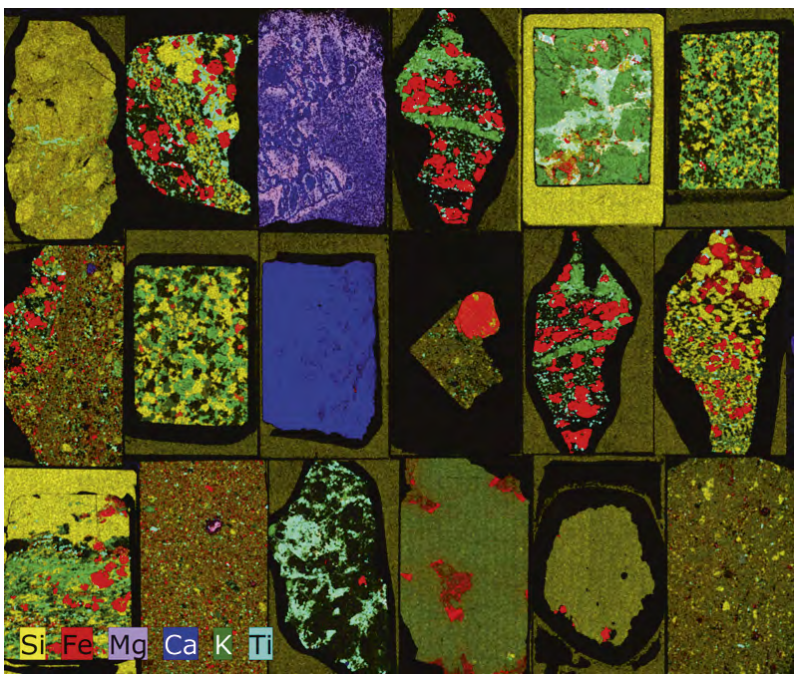
The M4 TORNADO is particularly suitable for forensic analysis. This includes examination of layered systems such as paint, extremely small material fragments and gunshot residue. It is also the ideal instrument for non-destructive analysis of documents and small works of art for the authentication or digitalization of collections.

Geology

The large sample stage of the M4 TORNADO is predestined for the analysis of geological samples. Phase analyses or the search for trace elements can easily be carried out to study geological processes such as rock formation or to evaluate the mineral content of ores. The M4 TORNADO software offers several options for analyzing, representing and storing mineralogical data.

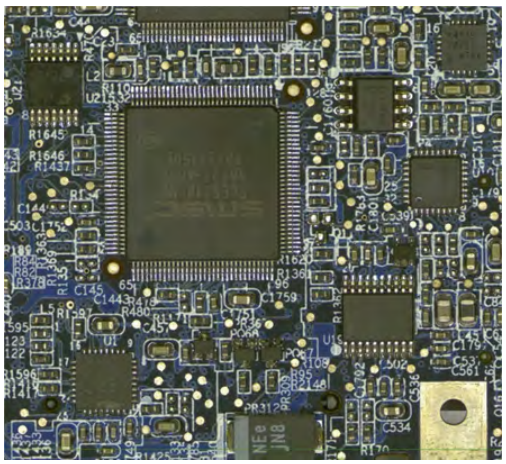
Multi-element distribution analysis of a hidden painting

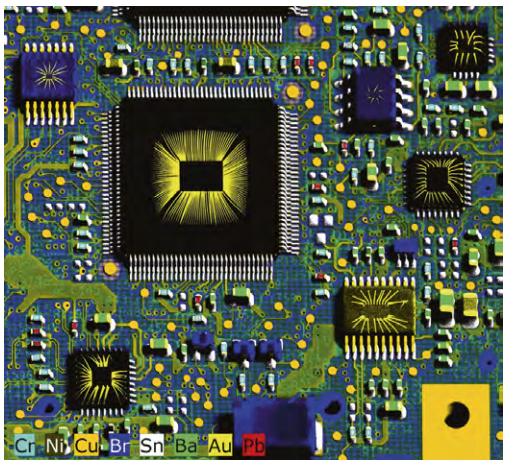
Left: Back of a painting by Max Klinger (1872, approx. 14.5 x 32 cm²) on a piece of wood covered with paper (wood approx. 8 mm thick). Right: A hidden painting is revealed by multi-element distribution analysis: the distribution of Cr, Fe, Cu, Ca, Pb and Hg contained in the used pigments, produces a false-color representation of the painting.



Screening of mineralogical thin sections with high resolution

Image size: 166 x 140 mm², scan resolution: 3320 x 2800 pixels, step size: 50 µm, dwell time: 1 ms/pixel.





Mosaic image and hot spots of a PCB

Left: Mosaic image of the analyzed PCB.
Right: Element distribution for hazardous elements (Br, Pb, Cr) and for Au (shows the bond wires of the integrated circuits).
Image size: 44 x 40.6 mm², scan resolution: 2750 x 2538 pixels,
step size: 16 µm,
dwell time: 5 ms/pixel.

Scanning for heavy metals and rare-earth elements

Rare earth elements or rare metals are increasingly in demand in many industries and as natural resources are limited, the recycling of used materials is more important than ever.

With the increased awareness of environmental and health hazards, the identification of substances that pose such risks is also becoming increasingly important.

The M4 TORNADO can be used to determine rare-earth elements, heavy metals, and other hazardous substances down to the ppm range. The qualitative analysis of single points or the examination of element distributions is possible for numerous sample types. These include electronic components, toys, consumer goods and many others. The high excitation efficiency of the M4 TORNADO enables rapid screening and detection of smallest traces.

Bioscience

The examination of metabolism in biological samples can provide valuable information on environmental conditions, health or diseases. An important indicator is the distribution of essential elements. Their allocation in plants and animal organs can be investigated with the M4 TORNADO with high spatial resolution and high sensitivity. The variable vacuum settings and optional helium purge allow sensitive samples to be screened without causing any damage.

Element maps of an autumn leaf

Image size:
110 x 74.6 mm²,
scan resolution:
2200 x 1492 pixels,
step size: 50 µm,
dwell time: 10 ms/pixel.

The Powerful Software

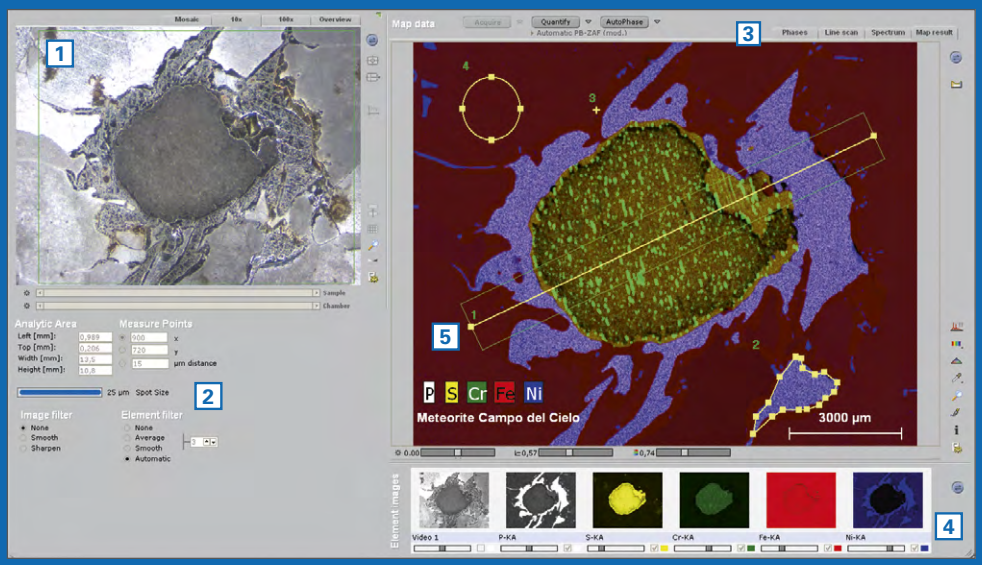
Getting the most out of your measurement data

Brukers longstanding expertise in EDS analysis has been incorporated into the powerful M4 TORNADO analysis software, which offers maximum functionality and user-friendliness.

In addition to point and line scans, the position tagged spectrometry option HyperMap enables high-speed scans of areas. The complete spectroscopic information for each measured location is collected and stored in a multi-dimensional data cube allowing comprehensive data evaluation. HyperMap supports extremely convenient data mining, both on- and offline.

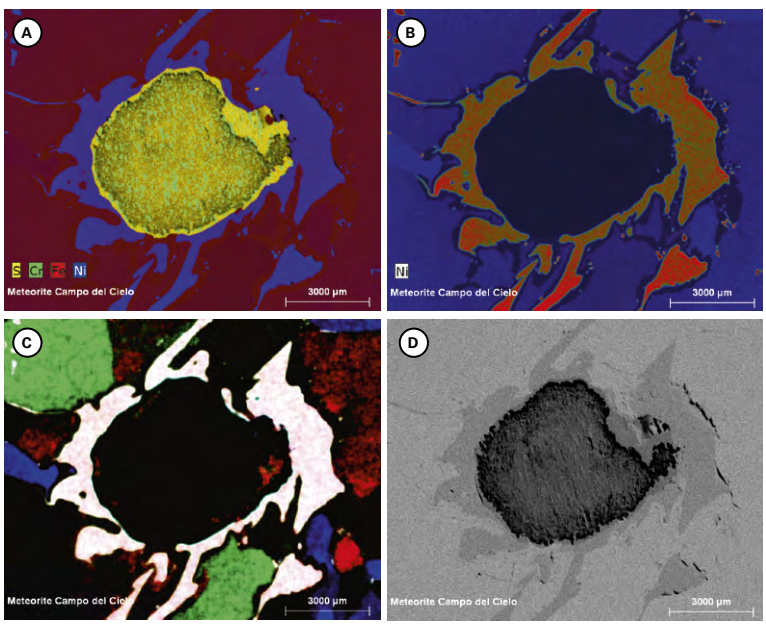
HyperMap example performed on an iron meteorite

1. Video control with mosaic image, 10x/100x magnification
2. Mapping acquisition controls
3. Data evaluation tabs
4. Single element distributions
5. Data display with definable data access tools: line, point and objects



Analytical tools for evaluating the HyperMap data cube

Variable display options allow optimized display of specific sample features: from multi-element display to variable intensities, crystal domains or density variations based on X-ray backscatter behavior.



Data display options
Multi-element mapping (A), false color element display (B), diffraction map showing the distribution of Bragg diffraction lines from specific crystal domains (C), total X-ray intensity map (D).

Information from points, lines, and objects

Spectroscopic information can be extracted from a HyperMap data cube by using various data access tools such as definable objects, points or lines to analyze compositional differences within a measured area.

Point

The point option provides a quick overview of the most important components at selected positions. Individual points can be defined by placing a crosshair in the HyperMap image. The corresponding spectrum is displayed under the Spectrum tab.

Line scan

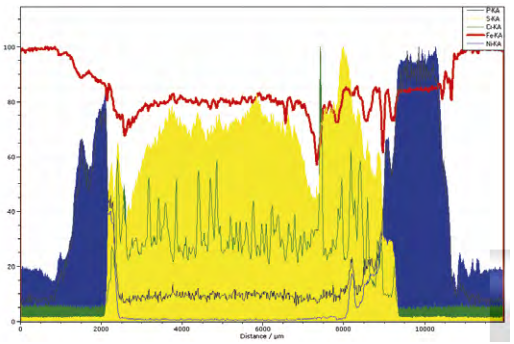
Arbitrary lines can be drawn within the HyperMap image to calculate the elemental composition. To improve the statistics and smooth the element distribution lines, the software can widen the scan line by adding adjacent pixels. The results of a scan are displayed under the Line scan tab.

Objects

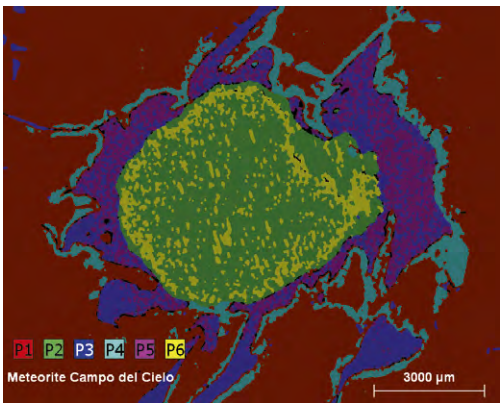
Objects of any shape (rectangles, circles, polygons) can be drawn on the map, resulting in a sum spectrum over the selected area. This function is extremely useful to improve count statistics for quantification and to compare similarly composed regions.

Phase analysis and chemometry

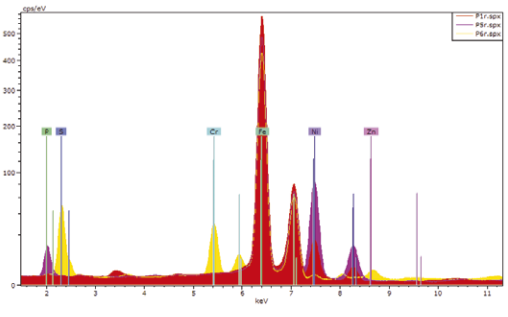
The phase analysis function allows to determine the distribution and proportion of the different phases in the scanned area.



Line scan
The line scan shows the relative intensity distribution of selected elements over the inclusion of an iron meteorite.



Phase analysis
Phase analysis clusters similar compositions as phases. The percentage share of the individual phases is calculated.



Spectra comparison
Spectra comparison between the phases in the phase analysis figure above:
P1 – red
P5 – pink
P6 – yellow

	Series	Net	[wt.%]	[wt.%]	Atom C [at.%]	Error [%]
Iron	K series	214751713	94,59	93,82	93,76	3,66
Nickel	K series	6274049	5,76	5,71	5,43	0,01
Copper	K series	7388	0,01	0,01	0,01	0,00
Zinc	K series	2017	0,00	0,00	0,00	0,00
Phosphorus	K series	89042	0,36	0,35	0,64	0,00
Sulfur	K series	37785	0,08	0,08	0,14	0,00
Chromium	K series	99229	0,03	0,03	0,03	0,00
		Total	**100,82**	**100,00**	**100,00**	

Quantification
Quantification results of phase P1.

Technical Data	
Sample types	Solids, particles, liquids
Sample chamber size	W x D x H: 600 mm x 350 mm x 260 mm
Stage	W x D: 330 mm x 170 mm, max. weight load: 7 kg
Measurement atmosphere	Air or adjustable vacuum with oil-free pump, 20 mbar in < 2 min, optional helium purge system
Sample travel	Max. travel: W x D x H 200 mm x 160 mm x 120 mm Mapping travel: W x D 190 mm x 160 mm Travel speed: up to 100 mm/s with TurboSpeed stage
Sample view	Two simultaneous live images from above with different magnifications for sample overview and precise positioning, lateral fisheye camera for the sample chamber overview
Excitation	1st tube: high brilliance X-ray tube with polycapillary X-ray optics Target material: Rh (optionally Ag, others on demand) Tube parameters: 50 kV, 30 W Spot size: < 20 µm for Mo Kα (17.5 keV) with polycapillary lens Filters: 8 excitation filters Optional 2nd tube: fine focus X-ray tube with collimator (0.5 mm, 1 mm, 2 mm, 4-pos collimator changer) Target material: W (optionally Rh, Mo, Cu, Cr) Tube parameters: 50 kV, 40 W Filters: 8 excitation filters
Detection	XFlash® silicon drift detectors, detection from Na to Am, optional simultaneous use of two detectors Detector area: 30 mm², optional second spectrometer and 60 mm² detector area Energy resolution: < 145 eV at Mn Kα and 300,000 cps input count rate (count rate Cu > 400,000 cps) Throughput: up to 550,000 cps output count rate with dual detector setup
Instrument control	State-of-the-art PC, Windows® 10
Instrument control functions	Complete control of tube parameters, filters, optical microscopes, sample illumination and sample positioning
Spectra evaluation	Peak identification, artifact and background correction, peak area calculation, quantification with standard-based and standardless models
Distribution analysis	"On the fly" measurement, HyperMap capability
Result presentation	Quantification results, statistical evaluation, element distribution (line scan, mapping)
Power requirements	100 - 240 V (1P), 50/60 Hz
Dimensions	W x D x H: 815 mm x 680 mm x 580 mm, 130 kg*
Quality & safety	DIN EN ISO 9001:2015, CE certified; Fully radiation protected system; radiation < 1 µSv/h

*Depending on configuration

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