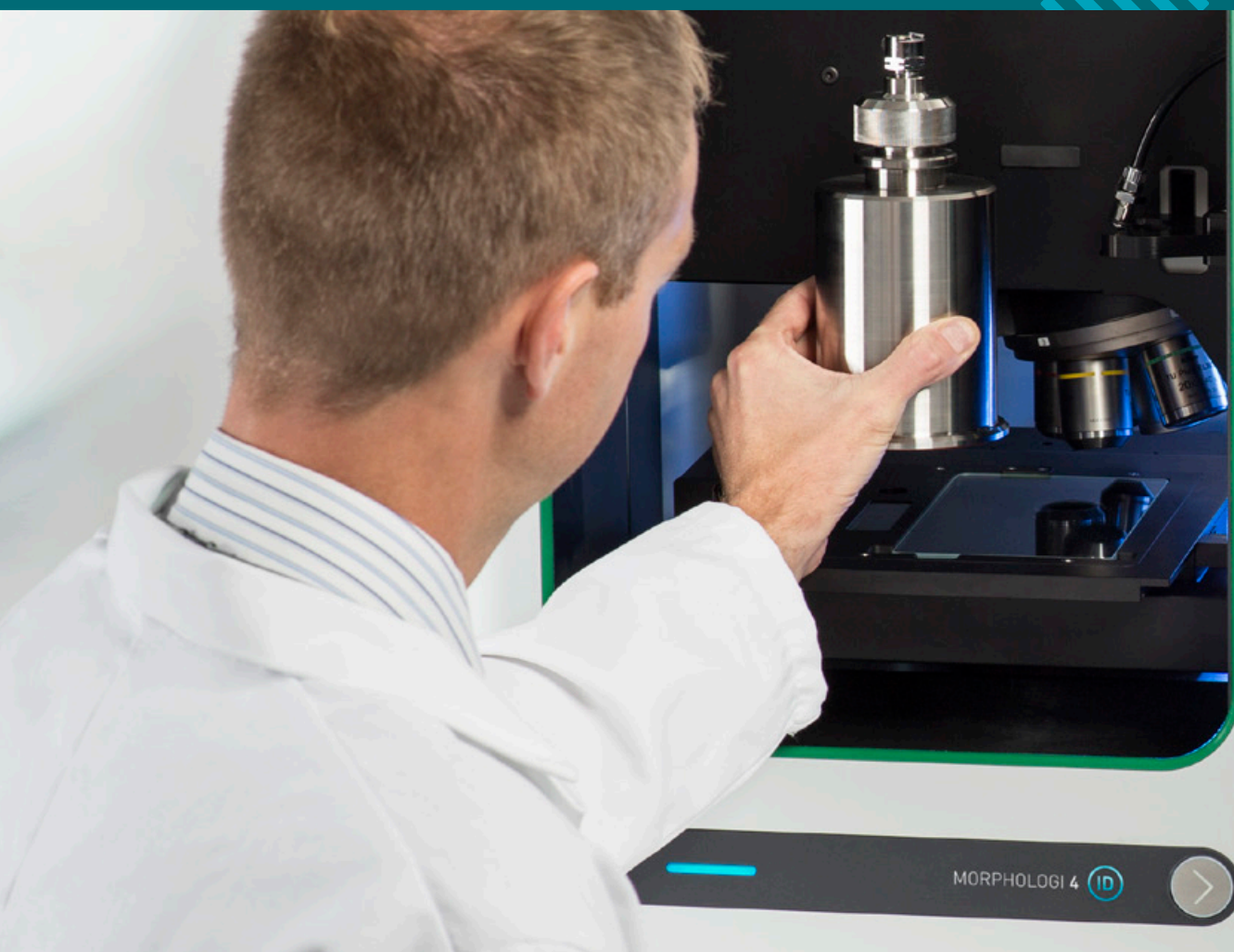




MORPHOLOGI 4 RANGE

Automated imaging for advanced
particle characterization



MORPHOLOGICAL IMAGING FOR YOU

Morphological imaging is fast becoming an essential technology in the laboratory toolkit for particle characterization. Providing **automated, rapid, and component-specific morphological information**, Morphologi instruments are employed to solve formulation and deformation challenges, optimize material properties, and create confidence throughout development and manufacturing. These systems enable process control and optimization and provide quick identification of the cause of process deviations.



“The Morphologi system produced databases of particle images which demonstrated the exemplary performance of our spray drying technology and toll manufacturing operation to customers.”

Hayato Kato
Preci Corporation, Japan



PHARMACEUTICALS

Active Pharmaceutical Ingredient (API) and excipient particle size and shape are critical material attributes which must be understood and controlled during formulation development and process scale-up for both innovator and generic

products. Morphologi delivers the data required to achieve this, and can also determine the component-specific API particle size required to establish *in vitro* bioequivalence for generics, minimizing associated clinical study costs.



ENERGY STORAGE / BATTERIES

Morphological descriptions can be used to correlate electrode powder attributes with battery performance, to support product development and ensure final product quality.

Morphologi systems also provide information on the chemical composition and structure of electrode materials, properties which are fundamental to battery performance.



POWDER METALLURGY / ADDITIVE MANUFACTURING

Metal powder properties such as particle size and shape are critical for powder metallurgy processes as they impact final component quality and performance.

Morphologi is used by metal powder producers and component manufacturers to ensure an optimum, consistent and traceable powder supply, mitigating the risk of costly part failure.



FORENSICS

Forensic analysis requires physical and chemical information to interpret evidence. The particle size, shape and chemical information delivered by Morphologi enables contaminant identification,

detection of counterfeit pharmaceuticals or illicit drugs, and examination of soils and other residues from crime scenes, to support the investigative process.



BUILDING MATERIALS

Cement is a complex mixture of minerals and additives, the component-specific particle properties of which affect final product performance. Morphologi allows the particle size and

shape of individual components in a cement blend to be fully characterized and compared between batches or products, to aid product development and solve production problems.



MINING AND MINERALS

The morphology of geological deposits helps trace the extent of natural disasters and predict the impact of future environmental events. Particle properties also determine the effectiveness of

abrasive minerals for use in cutting and polishing tools. Morphologi automatically generates the statistically relevant, component-specific particle data required to meet these challenges.



SPRAY DRYING

Spray drying techniques are employed across a range of manufacturing industries to produce granules with the correct size and shape to deliver the required fluidity.

Morphologi provides statistically relevant data to support the optimization of processes and to robustly deliver to these expectations.

WHY USE MORPHOLOGICAL IMAGING?

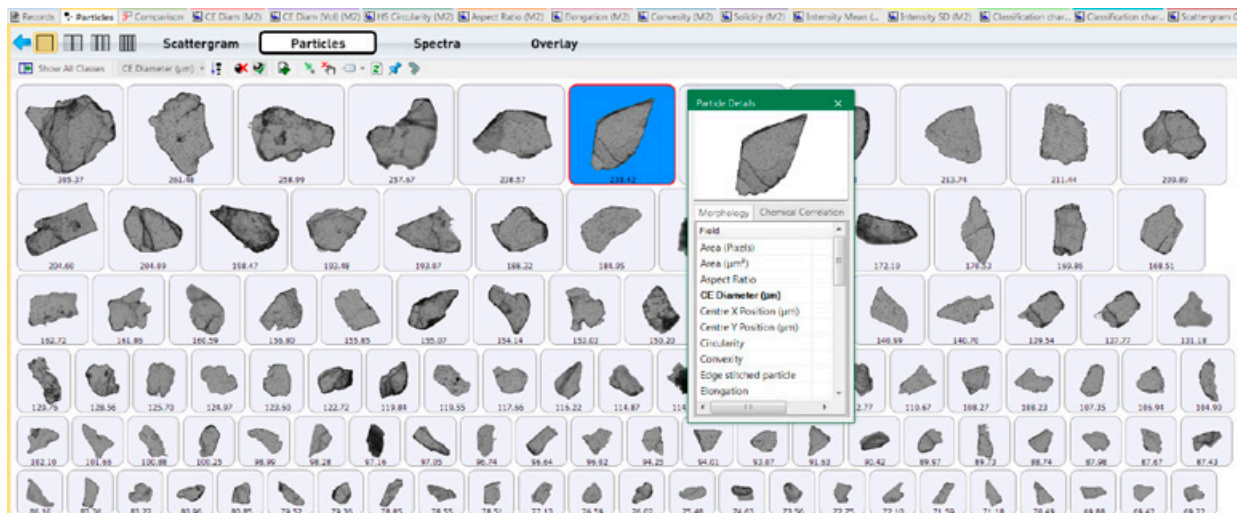
Morphological imaging applies the technique of automated static image analysis to provide a complete, detailed description of the morphological properties of particulate materials.

By combining particle size measurements such as length and width, with particle shape assessments such as circularity and convexity, morphological imaging fully characterizes both spherical and irregularly-shaped particles.

This enables deeper understanding of a sample's characteristics through precise detection of agglomerates,

foreign particles and other anomalous materials. It also delivers the data required to cross-validate other particle sizing methods which apply an equivalent-sphere approach to reporting particle size distributions.

Morphological imaging precisely characterizes individual particles within pre-dispersed samples of dry powders, wet suspensions, and particulates deposited on filters. Statistically representative distributions are constructed by rapidly and automatically analyzing hundreds of thousands of particles per measurement, providing valuable information on the whole sample.



A PICTURE paints a thousand particles

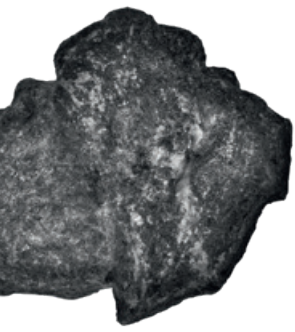
Individual 2D images of each particle are displayed together with the size and shape distribution for the whole sample. This provides a powerful visual verification of results, and can confirm and quantify the presence of agglomerates or unwanted particles in the sample dispersion.

EXPLAINS particle properties

Morphological imaging provides data on particle size, shape, and transparency in one measurement. Each particle in the sample is measured individually, providing high resolution and detailed information, which can be used to complement data from other techniques.

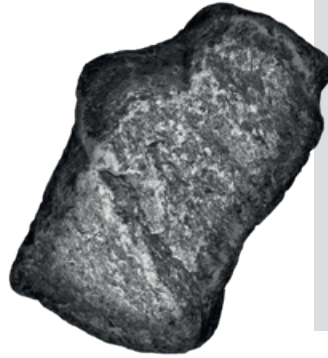
FASTER and more robust

Automated imaging measures many thousands of particles in less time than manual microscopy takes to measure just a handful - making the measurement much more statistically robust. Particle images are automatically and objectively captured, measured, analyzed and classified, minimizing operator subjectivity.



PARTICLE SHAPE

When particle size alone is not enough



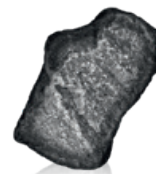
CASE STUDY

Reading Scientific Services Ltd., UK, develops fully validated particle size analysis methods in line with pharmaceutical regulatory requirements. To do this, they must ensure their methods give tight control over potential sources of variability. Particle shape measurements are used to troubleshoot suspected dispersion issues encountered during laser diffraction measurements.

In a recent project, variability of particle sizing results was observed, and a problem with the method was suspected. However, images from the Morphologi provided compelling evidence that the root cause was a change in particle shape during process scale-up.

Single particles or agglomerates?

Particulate samples can be prone to agglomeration which may not be easily detected by other particle sizing techniques. Analysis of individual particles in the dispersion in terms of their outline shape enables you to determine if, and to what extent, agglomerates are present.



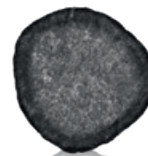
Single particle



Agglomerate

Regular or elongated?

Milling can change particle shape and size, which affects a material's processing behavior and final properties. By measuring shape parameters such as elongation or circularity, the overall sample form is monitored and process changes can be made if required.



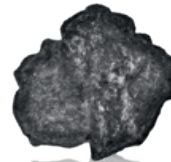
Regular



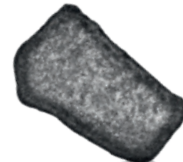
Elongated

Rough or smooth?

Powder flow and abrasive powder effectiveness are both influenced by particle surface texture. Particle shape parameters help assess if a powder is likely to stick in a hopper or if an abrasive powder has become worn.



Rough



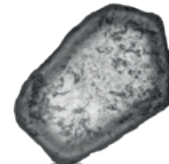
Smooth

Light or dark?

Mineral samples often contain a mixture of different particle types. Using greyscale images to measure physical properties such as the amount of light passing through or being reflected from the particle's surface helps to differentiate between these particles.

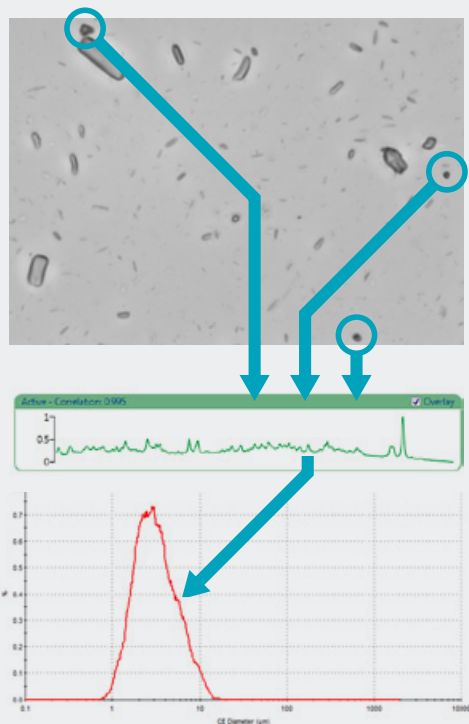


Dark



Light

WHY USE MDRS?



Component-specific morphology

Determine particle morphology of a component in a mixture; for example, API particle size in a pharmaceutical formulation for in vitro bioequivalence studies.

Identification

Detect and identify particles of interest; for example, contaminants or outlier particles.

Chemical composition

Investigate unknown particulate samples; for example, explore the mineral composition of geological samples or understand the electrode microstructure in battery materials.

Forensic investigation

Investigate components of illicit or counterfeit drugs, soil samples and other residues, to determine their source.

Track particles in a process

Follow the morphology of particles throughout a process; for example, changes in the API throughout a tableting process.

Deformulation or reverse engineering

Identify and characterize individual components within a mixture; for example, during generic drug development or cement research.

MORPHOLOGICALLY-DIRECTED RAMAN SPECTROSCOPY

Demand for new products with increased functionality requires the development of robust approaches to understand the properties of ever more complex multi-component formulations.

Engineering new product properties, or ensuring performance targets are robustly met, requires precise knowledge of the microstructure and form of each component. Morphologically-Directed Raman Spectroscopy (MDRS®) enables you to achieve this goal.

MDRS combines the power of morphological imaging with the established technique of Raman Spectroscopy to deliver component-specific microstructural insight.

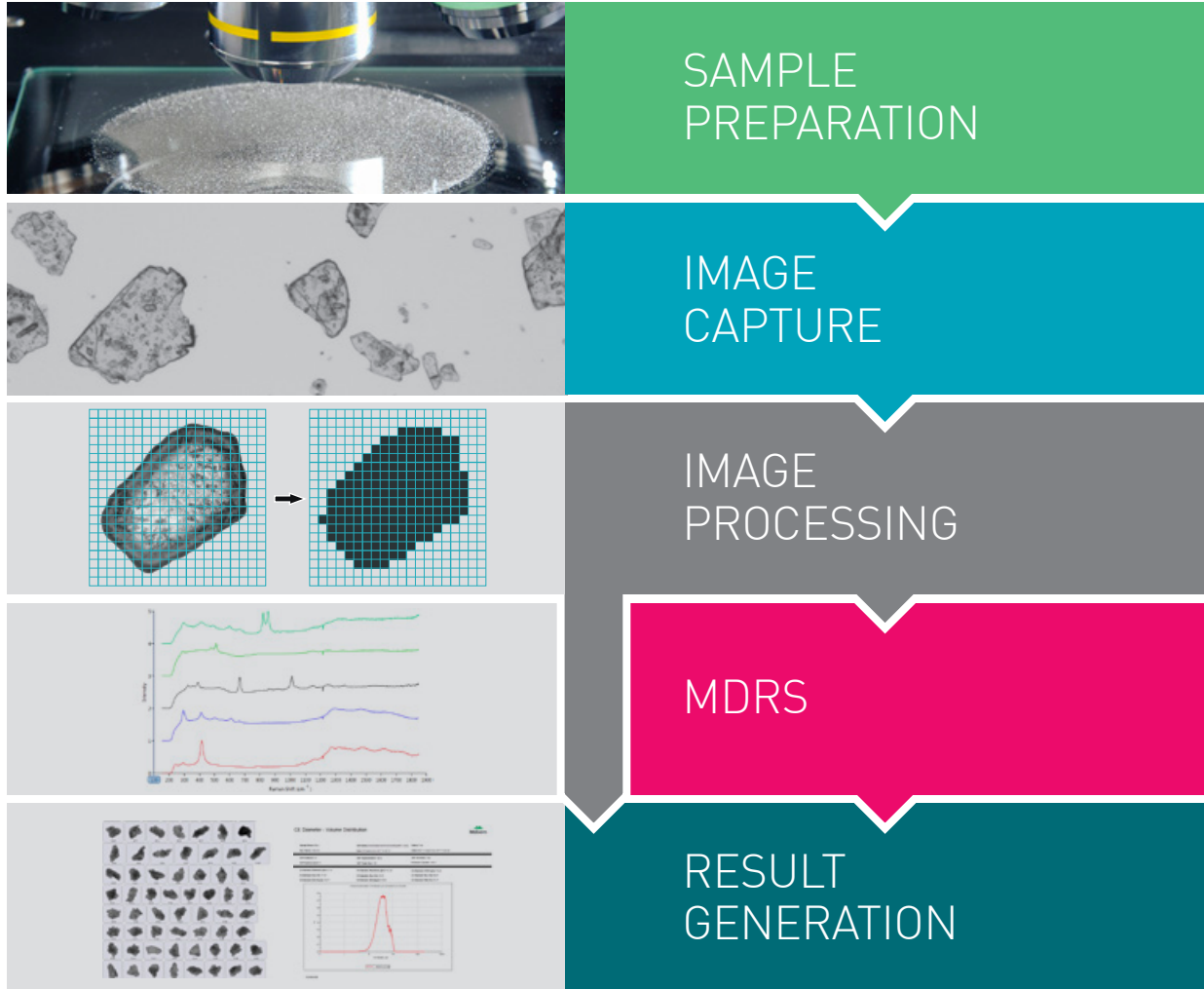
Raman spectroscopy is well recognized across industry and academia as providing the high level of chemical specificity required to identify components in a mixture, even to the degree of differentiating alternative forms of the same compound.

The seamless combination of precise particle size and shape data with the chemical identification delivered by MDRS gives you the power to unlock complex particle characterization problems.

“The Morphologi ID is an excellent tool for the characterization of size and morphological form, with the added advantage of enabling chemical identification of the species present.”

Dr. Ameneh Schneider
Austrian Cement Industry

MORPHOLOGICAL IMAGING WORKFLOW



CUSTOMER STORY

Particle Technology Labs, Chicago, USA, a leading service laboratory dedicated to quality particle sizing and characterization, traditionally used manual microscopy techniques to supplement laser diffraction and other particle sizing techniques which are limited by their assumption of equivalent spherical diameter. The PTL team made the decision to purchase a Morphologi system, which has allowed them to automate manual imaging methods, process large numbers of images in many different ways, and examine a wide variety of parameters.

This has provided detailed information and the extra insight required by their clients.

The Morphologi has quickly become their instrument of choice for characterizing elongated and non-spherical particles. The combination of speed, automation and walkaway functionality has maximized throughput and optimized use of operator time.

MORPHOLOGI 4

Flexible

The Morphologi 4 measures the particle size and shape of dry powders, wet suspensions and particulates on filters.

Designed to accommodate the diverse needs of a multidisciplinary R&D lab, it is the ideal replacement for costly and time-consuming manual microscopy.

Fast

Substantial time savings are achieved compared to manual methods, thanks to automated operation and simple data analysis.

Reliable

Robust, reproducible measurements are delivered via simple SOP-driven operation. All critical factors are carefully controlled and audited, from dispersion conditions, sample focus and illumination, through to data analysis and reporting.

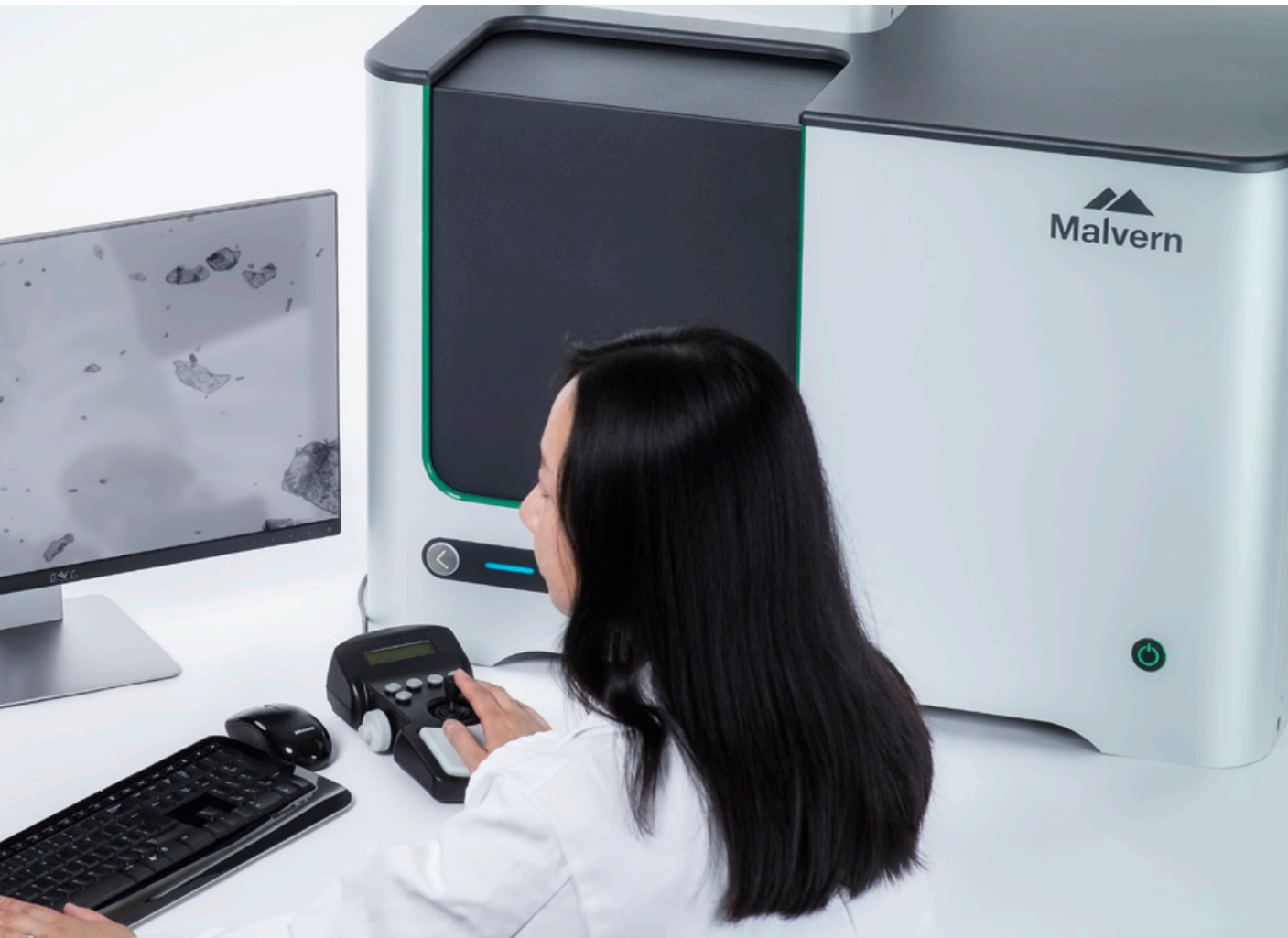
The result is non-subjective data you can rely on.

“The automated microscopy and image analysis functions are especially popular and have saved countless hours compared with using manual microscopy techniques.”

Prof. Andrew Rose

Southern Cross University
Australia





MORPHOLOGI 4 KEY FEATURES AND BENEFITS

- Broad particle size range from 0.5 μm to over >1300 μm enables size measurements of a wide range of samples
- 20+ morphological parameters deliver a highly-detailed description for deeper understanding of your particulate material
- SOP control, from sample dispersion to data analysis, provides simple and automated operation for robust, repeatable measurements
- Automated 'Sharp Edge' analysis enables detection of even low contrast particles
- High resolution microscope ensures quality particle images for optimum image analysis data
- Integrated dry powder dispersion unit delivers reproducible sample dispersion, critical to achieving meaningful results
- Dedicated sample presentation accessories enable measurement of a wide variety of sample types, including suspensions and filters
- Advanced data exploration tools generate maximum sample knowledge
- Advanced manual microscope mode and ability to return to particles of interest enables an even closer examination of unexpected particles
- 21 CFR Part 11 software option ensures regulatory compliance

MORPHOLOGI 4-ID

Unique

The Morphologi 4-ID offers an exclusive capability, combining all the benefits of automated static imaging delivered by the Morphologi 4 with chemical identification of individual particles by Raman spectroscopy in a single measurement.

Controlled

Unattended SOP-driven operation controls sample dispersion, morphological and chemical analysis in one easy method. It provides a clear route to robust, operator-independent results. Spectral acquisition conditions are easily customizable to each sample, enabling measurement of thermally-sensitive species and even weak Raman scatterers.

Insightful

This fully automated instrument provides both particle characterization scientists with limited spectroscopy experience and more experienced spectroscopists with a comprehensive understanding of their particulate samples.

“The Morphologi ID system has truly been invaluable to our particle characterization core facility. This instrument is the one instrument that provided the answer to ‘what is it?’ when characterizing particles.”

Dr. Amber Fradkin

KBI Biopharma
Colorado, USA





MORPHOLOGI 4-ID KEY FEATURES AND BENEFITS

- Patented MDRS capability delivers representative component-specific particle size and shape data for full characterization of your sample
- All the functionality of the Morphologi 4, combined with a dedicated Raman platform for both physical and chemical particle characterization in a single, automated measurement
- Automatically measures Raman spectra for hundreds or thousands of particles, saving valuable analyst time
- Intuitive software ensures suitability for experienced and non-experienced spectroscopists alike
- Easy correlation of morphological properties with chemical information provides the most comprehensive understanding of your sample
- 21 CFR Part 11 software option ensures regulatory compliance
- Adaptable workflows enable methods to be tailored to specific user or application requirements. Select particles for chemical analysis:
 - manually, from particle images
 - morphologically-directed, based on user-specified classifications (MDRS)
 - automatically and objectively by the software
- Ability to export spectra in industry-standard format supports unknown component identification using 3rd party spectral libraries
- Tight control of laser power and acquisition time enables measurement optimization for a wide range of materials, from weak Raman scatterers to those that are thermally sensitive

SAMPLE PREPARATION AND PRODUCT **ACCESSORIES**

Easy, reproducible, automated sample dispersion

Appropriate dispersion of the individual particles and agglomerates within a sample leads to robust and reliable results. Good spatial separation and representative sampling of the particles is required.

The integrated dry powder dispersion unit in both the Morphologi 4 and Morphologi 4-ID enables simple, reproducible preparation of dry powder samples. A precise amount of sample is dispersed automatically using a unique compressed air dispersion mechanism controlled from within the software, for reproducible dispersions every time.

Optional accessories

A range of instrument accessories support preparation of samples on microscope slides, in wet suspensions or on filters, extending the capabilities of both systems beyond the characterization of dry sample dispersions. Each accessory fits directly into the automated stage area and is easily selectable in the Morphologi software.

For chemical ID measurement, suitable sample substrates are available and particulate samples collected on filter membranes can also be measured, if the filter material is appropriate for Raman analysis.

ACCESSORIES FOR ANALYSIS OF PARTICLES IN SUSPENSION

2-slide and 4-slide holders

'Sandwiching' a few μL of a particulate suspension between a microscope slide and a cover slip is a traditional method of sample preparation for microscopy. Samples are presented in this form using either the 2-slide or 4-slide holder.

The 4-slide holder is supplied with each instrument, and the 2-slide holder can be purchased as an optional extra. Slides suitable for chemical identification applications are available.



Wet dispersion cell

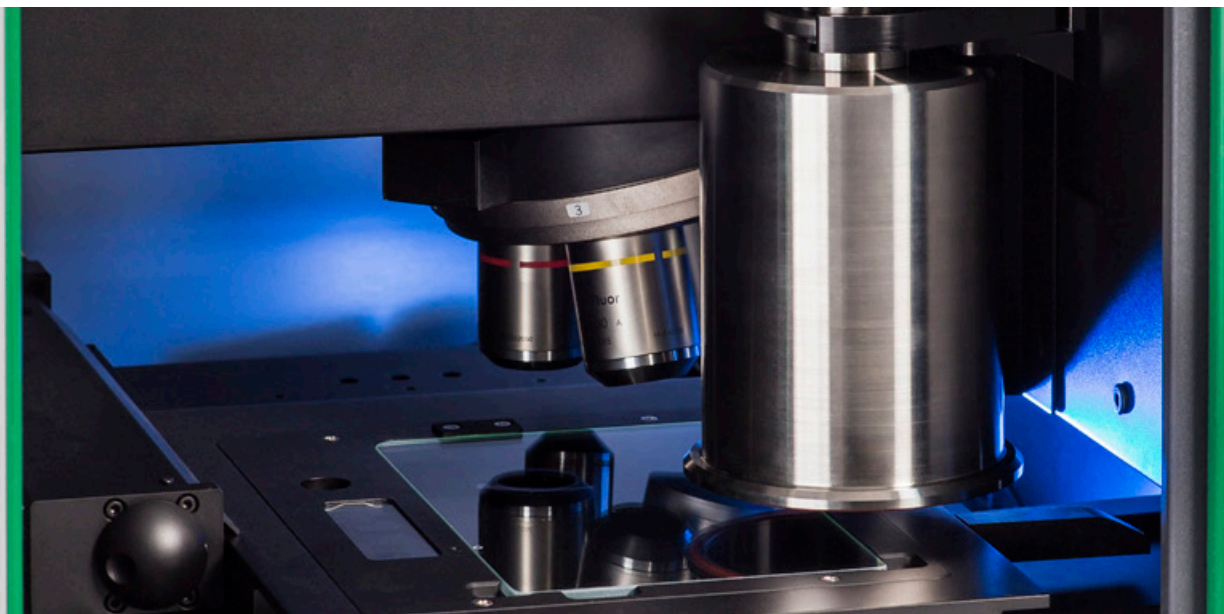
The wet dispersion cell allows between 2 mL and 6 mL of sample to be analyzed. This is particularly useful for characterizing larger suspended particles or where volumetric particle count is important.



Thin-path wet cell

The thin-path wet cell is designed for both morphological and chemical characterization of up to 100 μL of sample. It is ideal for applications such as the identification of subvisible particles in therapeutics (described by guidance in USP <787> and USP <788>), especially when a traditional membrane filtering approach may compromise particles of interest, such as protein aggregates.





25 mm and 47 mm diameter filter holders

Methods used to detect and characterize particles in suspension often rely on capturing the particles on a membrane filter. Dedicated filter holders (25 mm or 47 mm diameter) and also the 2-slide holder allow samples on filter membranes to be presented directly to the instrument for analysis.



Fused silica filters and holder

Fused silica filters are designed to enable the analysis of filtered samples containing low-contrast particles such as protein aggregates or contaminant particles.

The fused silica filters are housed in a support for ease of handling, and are presented to the Morphologi in the fused silica holder, which can hold up to 2 filters.



Twin 35 mm petri dish holder

The twin 35 mm petri dish holder provides an alternative means of measuring suspended particles that may be at risk of being deformed when dispersed into a cell.





PRODUCT SPECIFICATIONS AT A GLANCE

Technology	Morphologi 4 Static automated imaging	Morphologi 4-ID Static automated imaging combined with Raman spectroscopy			
Morphological analysis	Static automated imaging				
Particle size range	0.5 μm – 1300 μm (upper limit may be extended for some applications*)				
Particle properties measured	Size, shape, transparency, count, location				
Particle size parameters	Circle equivalent (CE) diameter, length, width, perimeter, area, maximum distance, sphere equivalent (SE) volume, fiber total length, fiber width				
Particle shape parameters	Aspect ratio, circularity, convexity, elongation, high sensitivity (HS) circularity, solidity, fiber elongation, fiber straightness				
Particle transparency parameters	Intensity mean, intensity standard deviation				
Integrated sample dispersion unit	For fully automated dispersion and measurement of dry powders. Manual or SOP control of dispersion pressure, injection time and settling time				
Illumination	White light LED: brightfield, diasopic and episcopic; darkfield, episcopic				
Detector	18 MP; 4912 x 3684 pixel color CCD array; pixel size 1.25 μm x 1.25 μm				
Optical system	Nikon CFI 60 brightfield / darkfield system				
Lens	2.5x	5x	10x	20x	50x
Particle size range in μm (nominal)	8.5-1300	4.5-520	2.5-260	1.5-130	0.5-50
Chemical analysis	N/A		Raman spectroscopy		
Size range for chemical ID			1 μm - 1300 μm *		
Spectral range			150 cm^{-1} to 2800 cm^{-1}		
Spectral resolution			6 cm^{-1} resolution measured on an atomic line source. Average of <8 cm^{-1} across the range.		
Laser specifications			Wavelength: 785 nm		
			Power output from spectrometer: \leq 100 mW		
			Power output at sample > 45 mW at max power		
			Laser spot size: 2 μm at 50x magnification		
Laser safety			Class 1		
Chemical identification method			Raman spectral correlation		
System					
Dimensions	810 mm (W) x 520 mm (D) x 685 mm (H) with carry handles: 1100mm (W) x 520mm (D) x 685mm (H)				
Weight	76 kg (84kg including carry handles)		80 kg (88 kg including carry handles)		
Power requirements	100-240 V ac 50/60 Hz (<100W load)				

*Sample and substrate dependent



WHY CHOOSE MALVERN PANALYTICAL?

We are global leaders in materials characterization, creating superior, customer-focused solutions and services which supply tangible economic impact through chemical, physical and structural analysis.

Our aim is to help you develop better quality products and get them to market faster. Our solutions support excellence in research, and help maximize productivity and process efficiency.

Malvern Panalytical is part of Spectris, the productivity-enhancing instruments and controls company.

www.spectris.com

SERVICE & SUPPORT

Malvern Panalytical provides the global training, service and support you need to continuously drive your analytical processes at the highest level. We help you increase the return on your investment with us, and ensure that as your laboratory and analytical needs grow, we are there to support you.

Our worldwide team of specialists adds value to your business processes by ensuring applications expertise, rapid response and maximum instrument uptime.

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- e-Learning training courses and web seminars
- Sample and application consultancy



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