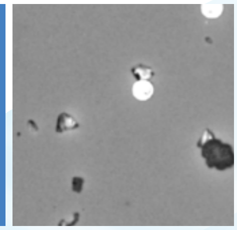
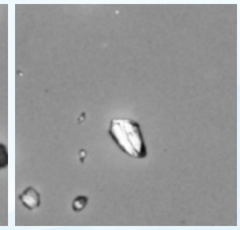
HORIBA

Raman

Analysis of Morphology and Chemical ID of Micro-Particles using Particle Correlated Raman Spectroscopy (PCRS)





Technical Note

RA TN22

Introduction

Micro-particles are used extensively for a wide variety of applications including food and agriculture, pharmaceutical, and advanced materials manufacturing. While traditional particle size analyzers can provide information on particle size and shape distribution, chemical identification is not possible using techniques such as dynamic light scattering, for example. Particle Correlated Raman Spectroscopy (PCRS) addresses this by combining high-resolution optical imaging with Raman spectroscopy to obtain both morphological and chemical information from particles as small as ~0.5 µm. PCRS supports wet, dry, and semi-solid samples and integrates automated particle detection, sizing, and spectral acquisition through ParticleFinder™, reducing the need for manual particle-by-particle selection. By correlating each particle's image with its Raman spectrum and reference library match, PCRS provides a systematic and traceable approach to particle characterization.

Figure 1 summarizes the overall workflow, from optical imaging to statistical analysis.

Sample Preparation

Sample preparation is essential for reliable PCRS analysis. Effective preparation isolates representative particles, minimizes artifacts, and ensures compatibility with both optical imaging and Raman spectroscopy. The appropriate method depends on the sample type. If the interest is in a single particle and the particle is large enough, it may be picked out with tweezers and placed directly onto a Raman-compatible slide, such as glass, silicon, or stainless steel for PCRS analysis. If multiple particles are of interest, the following standard sample preparation methods may be used, depending on the type of sample (wet, dry, semi-solid, etc.).

Wet Samples (Filtration Method)

Liquids such as environmental water, industrial solutions, or suspensions are commonly filtered to collect particulates. Raman-compatible filters (e.g., silicon or gold-coated polycarbonate) minimize background signal and provide good optical contrast. Pore size is selected based on expected particle size (typically 0.5–20 µm). Controlling sample volume helps avoid particle aggregation, and gentle rinsing can remove residual matrix components.

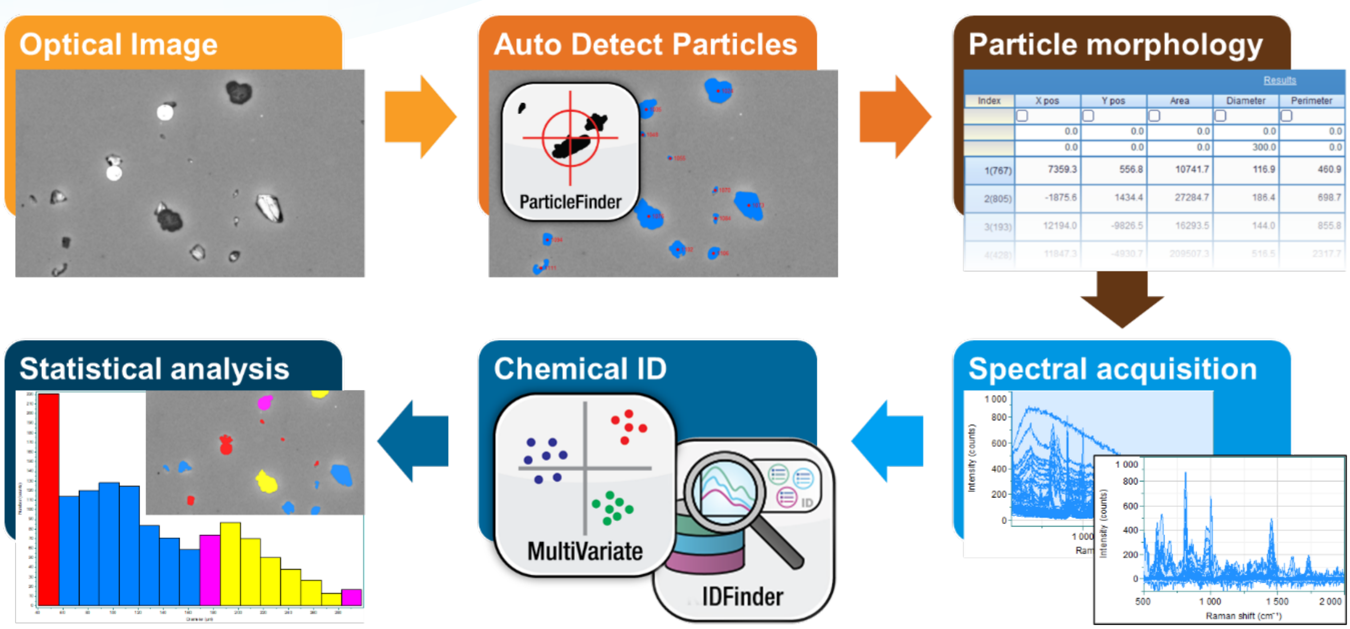


Figure 1: Particle Correlated Raman Spectroscopy (PCRS) workflow

Dry Samples (Disperser Method) [See HORIBA XD-100]

Powders, granules, and particulate solids can be dispersed directly onto Raman-compatible substrates (silicon, glass, or stainless steel). Low particle density ensures that particles remain isolated for accurate segmentation. Larger particles of interest may be manually positioned. This approach is suitable for raw materials, powders, and process-related solids.

Semi-solid Samples (Gels, Pastes, Creams, etc.)

Small, known quantities of semi-solid materials can be spread thinly onto a substrate using a coverslip, or diluted in a compatible solvent followed by filtration. Care is taken to avoid introducing artifacts during spreading. This method is used for identifying particulates embedded within viscous matrices.

Once the sample is properly prepared, the sample is presented to the Raman microscope for analysis with PCRS. The PCRS workflow is described below in 6 simple steps.

PCRS Workflow

Step 1: Optical Imaging of Particle(s)

High-resolution optical images are acquired to locate particles. Brightfield imaging is useful for opaque or strongly scattering particulates, while darkfield enhances contrast for transparent or low-contrast particles. Transmission imaging may be used with transparent substrates. Appropriate imaging mode selection and illumination settings improve segmentation accuracy and ensure alignment between the optical and Raman measurements.

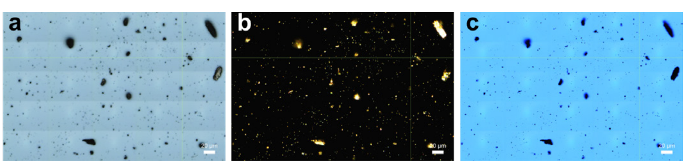


Figure 2. Optical imaging of particles on a glass slide using a) reflected brightfield illumination, b) reflected darkfield illumination, and c) transmitted brightfield illumination.

Step 2: Auto-Detection of Particles

After acquiring a suitable image, ParticleFinder™ automatically detects particles using threshold-based segmentation options. Automated detection reduces operator-dependent variability and facilitates consistent screening of large particle sets.

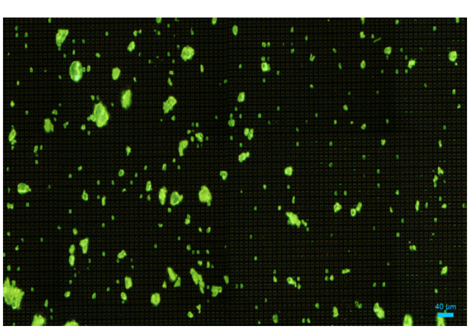


Figure 3. Automated particle detection using ParticleFinder™

Step 3: Particle Morphology

ParticleFinder™ calculates morphological parameters (e.g., size, circularity, aspect ratio) for each detected particle and their statistics. Users may filter particles based on these characteristics to select those most relevant for Raman analysis.

Index	X pos	Y pos	Area	Diameter ▼	Perimeter	Major axis	Minor axis	Ellipse ratio	Circularity	Brightness	Feret max diam.	Convexity	Elongation	Volume	Image
Filter min															
Filter max															
4224	14786.20	33160.42	1642.92	45.74	227.65	63.78	37.26	0.58	0.63	176.00	58.50	0.76	17.51	27822.81	
4225	16245.54	33026.15	1654.93	45.90	238.90	65.91	36.34	0.55	0.60	129.00	78.21	0.80	15.46	27351.32	
4226	13593.59	32968.07	1657.01	45.93	175.79	51.94	43.52	0.84	0.82	196.00	55.59	0.88	45.25	30901.09	
Mean	15476.38	32651.36	95.90	8.33	32.06	10.46	7.32	0.78	0.87	131.01	10.66	0.95	77.50	1145.39	
StDev	1302.64	575.11	311.25	7.26	34.85	10.56	6.16	0.17	0.09	42.24	10.44	0.05	29.49	11783.31	
Median	15347.99	32629.80	23.56	5.48	18.81	6.09	5.17	0.83	0.90	128.00	6.43	0.97	100.00	50.83	

Figure 4. Results table of ParticleFinder™ showing calculated morphological parameters of all detected particles

Step 4: Spectral Acquisition

Raman acquisition parameters—such as laser power, integration time, and focus—are optimized for the sample. Spectra may be collected using single-point measurements, multi-point averaging for heterogeneous particles, or full particle-level mapping, when necessary. Automated stage movement ensures spatial correlation between optical and Raman data.

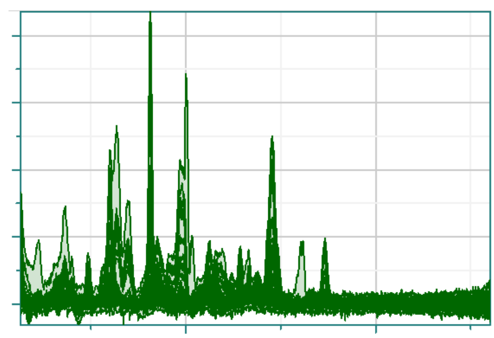


Figure 5. Overlaid Raman spectra of all detected particles

Step 5: Chemical Identification

Acquired spectra are compared against reference libraries to assign chemical identity. For each particle, the optical image, location, Raman spectrum, and identification are stored, generating a traceable dataset suitable for research, quality assurance, or contamination investigations. Automated matching improves consistency and reduces interpretation time.

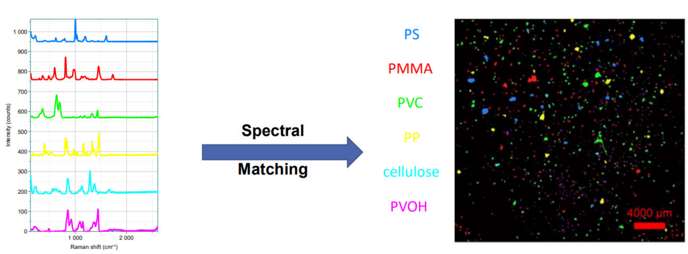


Figure 6. Optical image with particles recolored based on chemical identity

Step 6: Statistical Analysis and Reporting

Following identification, particle populations can be analyzed statistically by chemical ID, including size distributions, frequency of specific particle types, morphological trends, and spatial distribution across the sample. These results can be compiled into structured reports for regulatory documentation, internal records, or long-term monitoring efforts.

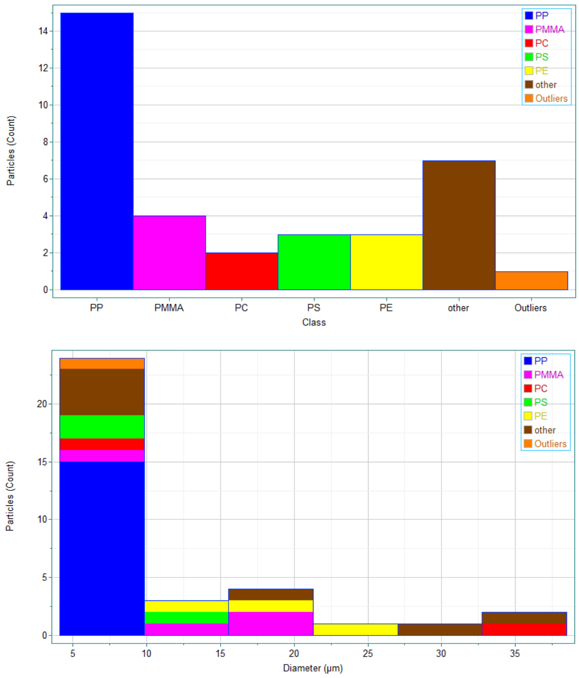


Figure 7. Statistical reporting by chemical ID of (a) the number of each type of particle and (b) the diameter of each type of particle

Applications of PCRS

PCRS is broadly applicable to any workflow where understanding particle composition and morphology is critical. Key application areas include:

- **Polymers:** identifying microplastics, polymer blends, additives, fillers, and degradation products
- **Pharmaceuticals/cosmetics:** analyzing particulate matter in drug products, identifying foreign or intrinsic particles, verifying raw materials, supporting contamination investigations, characterizing excipients or API-related particulates, and supporting particulate analysis in alignment with USP <788> workflows by enabling chemical identification of particles collected during visual or microscopic inspections
- **Semiconductors:** mapping defects, particulates, and process-generated residues
- **Batteries and Energy Materials:** characterizing active materials, contaminants, binder particles, and degradation products
- **Environmental Monitoring:** identifying particulates in water, soil, or air (e.g., microplastics, inorganic debris)
- **Forensics:** identifying trace particles such as fibers, paints, glass fragments, and other unknown debris to support source identification and evidence analysis
- **Industrial Manufacturing:** verifying material identity, monitoring particulates from wear, abrasion, or contamination
- **Materials Research:** studying composite materials, coatings, and heterogeneous particulate systems

These applications benefit from PCRS's ability to correlate particle morphology with definitive chemical identity, particularly for heterogeneous or visually ambiguous materials.

Summary

PCRS provides a structured, reproducible workflow for analyzing particulates and contaminants across varied sample types. The method supports both targeted examination of individual particles and high-throughput characterization of larger populations. By integrating optical imaging, automated particle selection, spectral acquisition, and chemical identification, PCRS enables complete, consistent and traceable particle analysis in research, industrial, and environmental applications.

Key Benefits of PCRS

- **Combined morphological and chemical analysis:** Provides both physical and chemical information from individual particles
- **High spatial resolution:** Can analyze particles down to ~0.5 µm
- **Supports multiple sample types:** Supports wet, dry, and semi-solid materials
- **Automated and reproducible workflow:** Reduces manual labor and operator variability
- **High-throughput:** Speeds up analysis compared to manual methods
- **Versatile material identification:** Works with organic, inorganic, polymeric, biological, and carbonaceous materials
- **Enhanced data quality and confidence:** Direct linkage of images to spectra improves identification accuracy
- **Handles complex or heterogeneous samples:** Effective for mixed-material populations
- **Streamlined analysis for QC and research:** Facilitates rapid characterization, contamination investigations, and material verification

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