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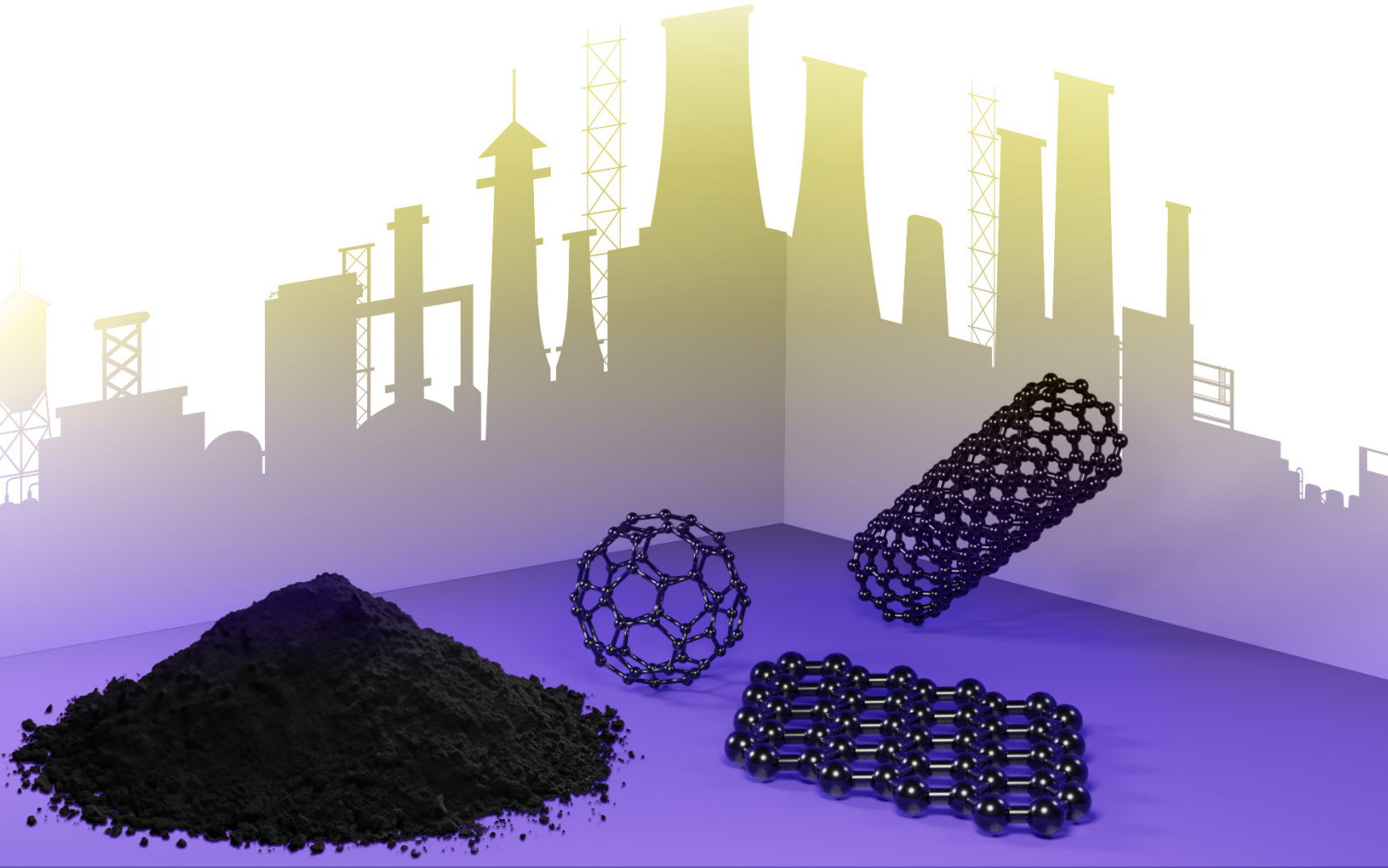


Analysis of carbon Raw Materials For Energy Challenges

www.horiba.com/carbon

For raw materials producers and electrodes manufacturers

Analysis of Carbon Materials, a Challenge for New Energy Sources and Storage

The need for measurement of raw carbon material for energy

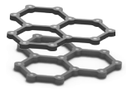
Analysis of carbon materials is crucial for raw material and electrode manufacturers, suppliers for batteries, electric vehicle manufacturers, and other users of carbon raw materials.

Ensuring the quality and consistency of carbon materials used in energy storage and conversion devices can be done by studying their level of purity, their physical structure and their performance.

How to measure each of these parameters?

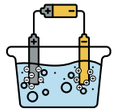
Purity of raw carbon

- Measure of concentration of organic and inorganic trace and ultra-trace.



Integrity and stability of carbon structures

- Inspection of crystallinity levels and detect defects and disorders.
- Examine chemical changes on the surface that affect stability (oxidation, functionalization).
- Determine particle characterization (size, diameter, aggregates, distribution).



Electrode performance

- Measure the particle size distribution.
- Monitor intercalation capacity.
- Evaluate electrode aging.
- Determine elemental composition before and after exposure to harsh conditions.

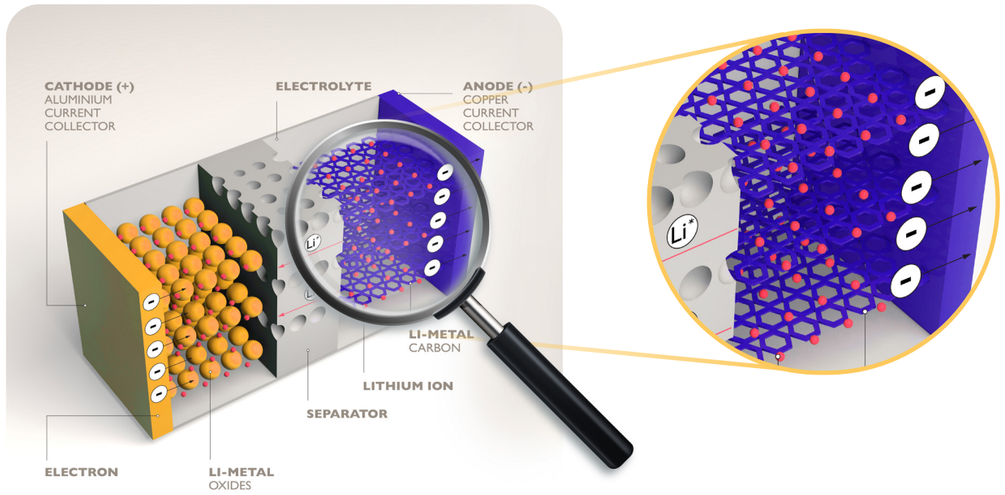
What carbon allotropic forms are relevant in the context of energy?

carbon manifests in various forms, each contributing uniquely to different applications:

- **Graphite**: stable, conductive anode in batteries for energy storage.
- **Carbon black**: boosts electrode performance in batteries, supercapacitors.
- **Carbon nanotubes**: advance energy storage with mechanical, electrical prowess.
- **Activated carbon**: key in carbon capture, high adsorption capacity.
- **Hard carbon:** high energy storage, stability as anode material.

Carbon serves as a resource extensively employed in battery fabrication, comprising a major part in their electrodes. Given the omnipresent presence of batteries in our everyday tools, gadgets, and transportation systems, the demand for carbon in energy storage and production has surged.

The combination of diverse techniques can offer a full characterization of carbon material, providing a robust analytical framework for investigating the properties, composition, and quality of carbon materials which in turn assess the quality of the future battery.



Raman Spectroscopy

Structural properties (crystallinity) of carbon

Elemental Analysis

Contaminant levels (O, N, H)
Carbon concentration

Inductively Coupled Plasma (ICP) with Electrothermal Vaporization (ETV)

Detection and quantification of trace elements in carbon

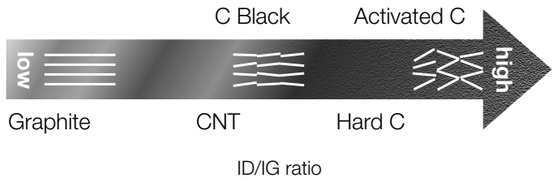
Particle Characterization Analyzis (PCA)

Size, shape, and surface properties of carbon materials

Fast Evaluation of the Crystallinity of Carbon

Raman measurement using Qcarbon, for fast carbon quality control

In Raman spectroscopy, the ID band reflects disorder or defects in carbon materials, while the IG band shows the presence of well-ordered carbon structures. Therefore, the ID/IG ratio is a quick indicator of the degree of disorder, or structural defects, present in carbon-based materials.



XploRA and Qcarbon

The XploRA Raman microscope, along with the Qcarbon app, can analyze raw materials or final electrode devices by:

- Analyzing spectra of each carbon form, and determination of the ID/IG ratio.
- Mapping the sample to follow the local changes in carbon metal organization.

XploRA and Qcarbon main features

Quality Control measurement of carbon

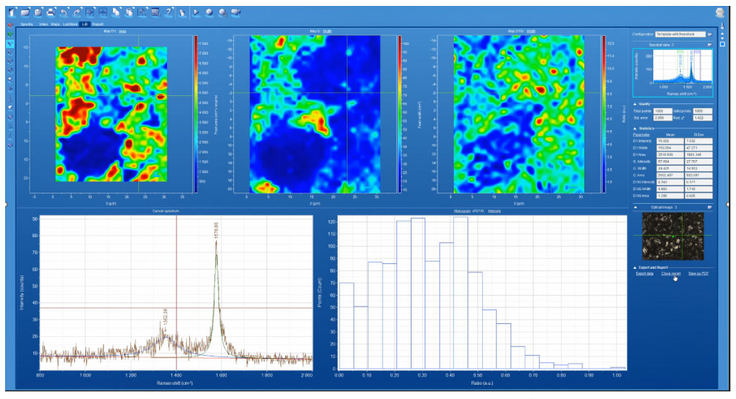
Full automated solution:
- Crystallinity of carbon
- carbon form determination

No sample preparation

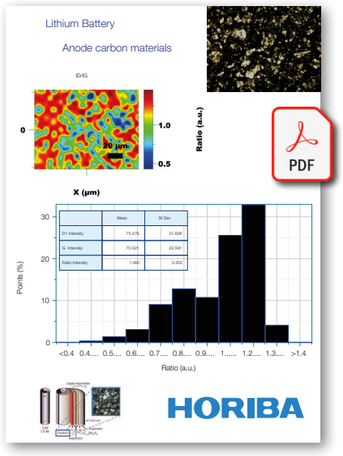
Non destructive method

XploRA

1-click analysis with fully automated data processing: peak fitting, QC check, D, G, D/G ratios and statistics

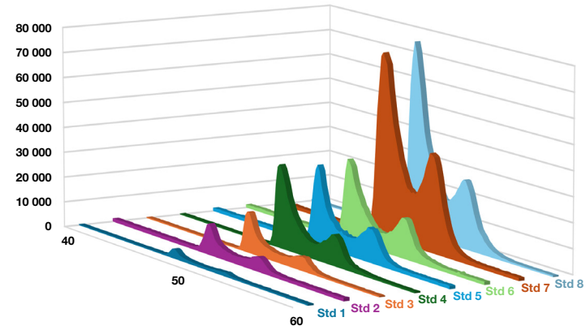


Example of results and reports obtained witth Qcarbon



Low Detection Limits of Impurities

ETV-ICP-OES for highly pure carbon



Surface measurement for fast concentration determination

ETV-ICP-OES main features:

Ultra-trace and major elements measured simultaneously

No tedious sample preparation

High sensitivity (at ppb level)

Fast acquisition speed (< 2 min/sample)

ETV-ICP-OES

- Thanks to the Photomultiplier tube as a detector, transient signals are quickly measured.
- High spectral resolution to get rid of complex matrix.
- Adding a polychromator and a monochromator to the instrument offers great flexibility
- Single integrated software
- Reprocessing results is affordable
- No sample preparation, no acid required
- Integrity of the sample
- Small sample quantity needed
- Upgradable on standard ICP-OES

Ultima Expert

ETV-4000

Size distribution and surface area

Particle characterization analyzer for size of carbon raw materials

Carbon particles are characterized by Static Light Scattering (SLS), a technique which measures light scattered at different angles from particles energized by laser source(s). **The particle size distribution and surface area of carbon materials influence their electrochemical performance, while in catalysts, the pore structure and surface morphology affect catalytic activity.**

Partica **LA-960V2** main features

Carbon particle size analysis

- Dry module to evaluate carbon raw material
- Measurement range from 10 nm to 5000 µm
- Small amount of sample per evaluation

LA-960V2

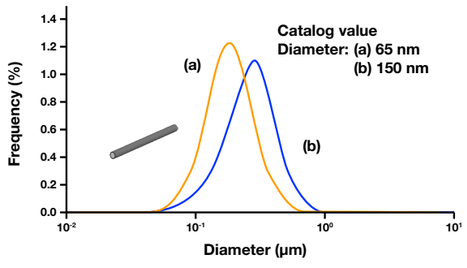
The **Partica LA-960V2** can analyze particles of carbon powder, with a dedicated module. Its wide dynamic range can characterize very small particles.

- Measurement range: 10 nm ~ 5000 µm
- Sample amount: 10 mg ~ 5 g
- Dispersant method

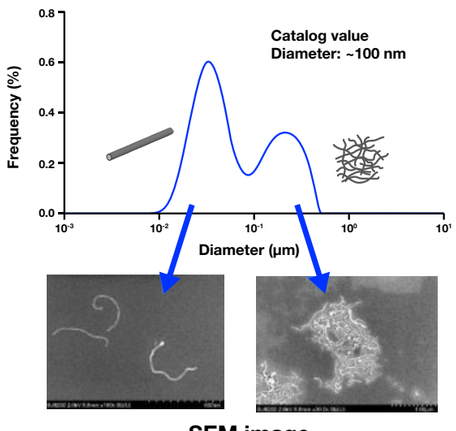
Partica CENTRIFUGE*

Use the Partica CENTRIFUGE CN-300 to access the CNT diameter and aggregation state.

- Measurement range: 10 nm ~ 40 µm
- Sample volume: 10 - 50 µl or 1500 µl depending on the measure mode
- Friendly software and easy cell maintenance



The graph shows the presence of both isolated and aggregated CNTs.



SEM image

* only available for some countries

Carbon concentration

Complementary techniques

The analysis of carbon, oxygen, and nitrogen provides critical information about the composition and purity of battery materials, influencing battery performance in multiple ways.

EMGA-Expert Analyzer can measure:

- Oxygen and nitrogen impurities of carbon powder
- Degradation of battery performance from presence of impurities in oxygen and nitrogen to oxygen valence.

EMGA main features

- **Evaluation of impurities contents**
- **Down to very small sample amount (less than 100 mg)**
- **Easy determination down to the ppm level**
- **Temperature ramp method to discriminate element bonded origin**
- **Fast analysis and low maintenance costs**

EMGA Expert

Sample mass (g)	Hydrogen mass (%)
0.0304	0.2571
0.0315	0.2574
0.0321	0.2599
Avg.	0.2582

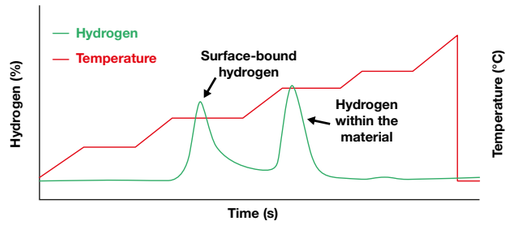
Accurate results with only 30 mg sample.

Sample mass (g)	carbon mass (%)
0.3059	0.0200
0.3061	0.0201
0.3055	0.0199
0.3057	0.0198
0.3059	0.0197
Average	0.0199
Standard deviation	0.0002
Coefficient of variation (%)	0.7900

Result of carbon content in $LiCoO_2$

EMIA main features

- **Evaluation of carbon and Sulfur concentration in material**
- **Few amount of sample (less than 1 g)**
- **Easy determination from 100% down to ppm level**
- **Navigation assisted operation**



EMIA Expert

The EMIA analyzers measure carbon in materials. The technique combines heating combustion in an oxygen stream and Infrared (IR) detection. carbon is measured as carbon dioxide (CO_2) and partly carbon monoxide (CO) by the nondispersive infrared detectors.

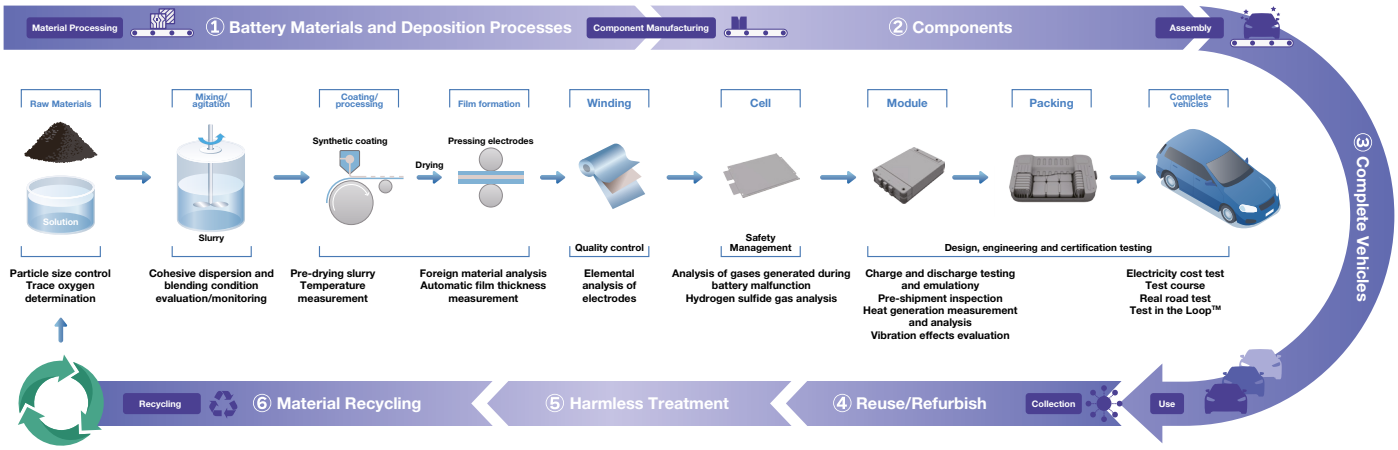
EMIA-Expert Analyzer can measure:

- Electrode conductivity by carbon content measurement
- Control of chemical treatment and process by sulfur content measurement

Energy innovation with HORIBA

HORIBA believes that it is important to operate each energy source in an optimal manner with high efficiency, low emissions, and minimal energy loss, and we are committed to working together with key players in the industry to realize a new era of **"generating," "storing," and "using" energy in a smart way, from the aspects of analysis and measurement**.

HORIBA not only helps to get carbon as raw material for energy, but also contributes to the development of **storage battery manufacturing and its recycling through a wide range of measurement and analysis technologies and engineering,** from R&D of battery materials, performance evaluation, production management, support for electric vehicle development to recycling, from particles to vehicle, then back to particles.



More about HORIBA

The HORIBA Group, made up of 49 companies in 27 countries, is a leading company that provides **analytical and measurement systems** throughout the world. HORIBA business is evolving in the markets of automotive, process and environmental instruments, medical diagnostics, semiconductor instruments and scientific instruments. It is our continual source of joy and pride that our analytical and measurement business can contribute to **global environmental conservation, safety and health, and moreover, to mitigating energy problems**.

Omoshiro-okashiku
Joy and Fun

おもしろおかしく

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