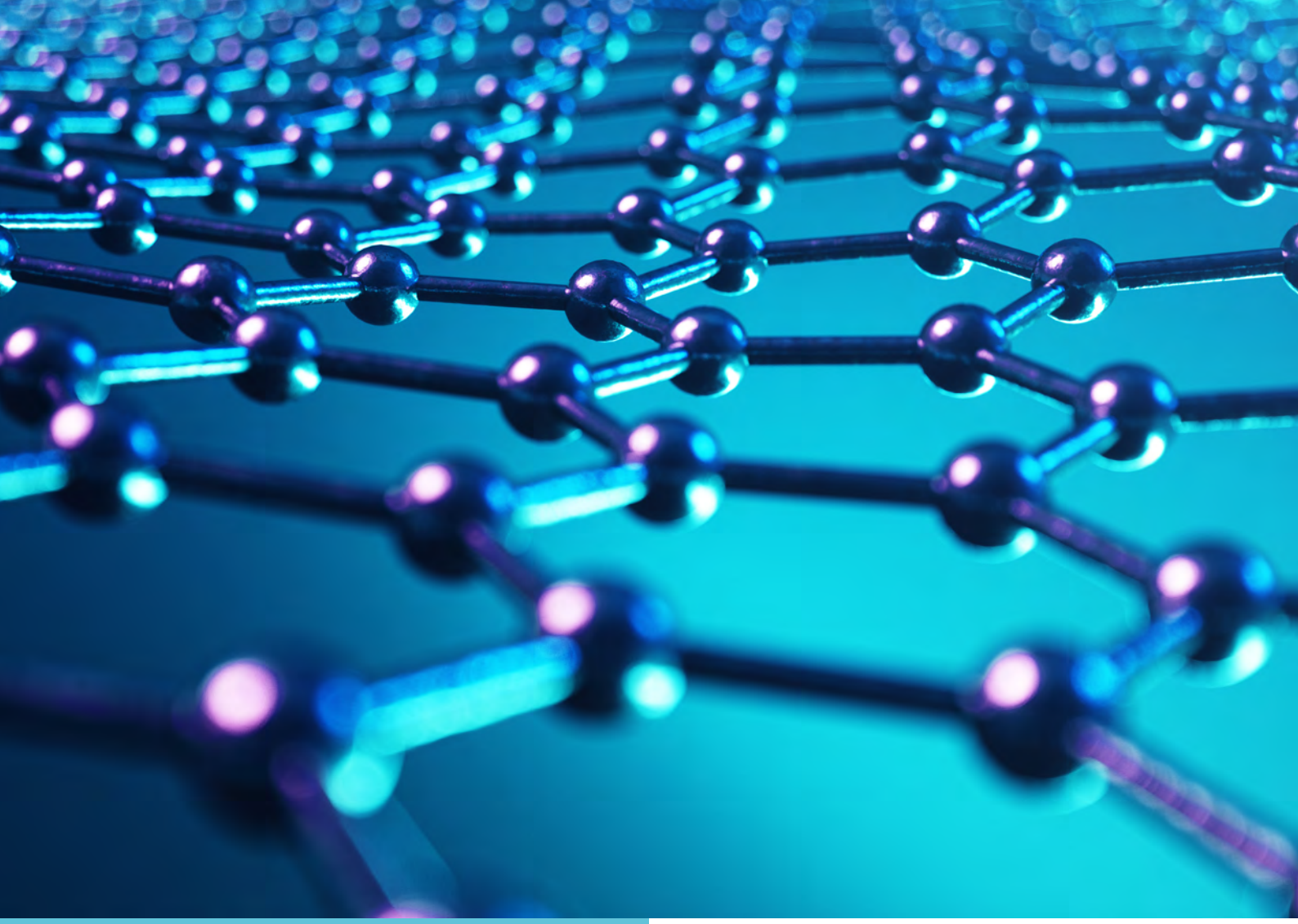


Carbon materials

Applied analytical chemistry for the characterization of critical QC parameters

PEOPLE
YOU
CAN
TRUST

Metrohm

A comprehensive portfolio

Due to properties such as, mechanical strength, high electrical and thermal conductivity, optical transparency, and more, carbon materials have become the subject of research for many applications.

We are one of the leading manufacturers of instrumentation to study carbon materials. Numerous parameters can be determined with our portfolio of instruments and methods ranging from traditional wet chemistry to electrochemistry and to the latest, non-destructive spectroscopic methods. We can support you in your research on the following carbon materials:

- Graphene, and related materials, such as graphene oxide (GO), and reduced graphene oxide (rGO) used, e.g., for flexible touch panels, organic light emitting diodes (OLED), solar cells, supercapacitors, and electromagnetic shielding.
- Carbon nanotubes (CNTs) used, e.g., as composite reinforcement material, in super capacitors, molecular sensors and hydrogen containers.
- Graphite used, e.g., as anode material in lithium ion batteries.
- Carbon black used as pigment in rubber and automobile tires and, more recently, as conducting pigment for printing applications.
- Hard carbon used in lithium and sodium ion batteries.

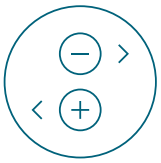
The following table gives you an overview of frequently analyzed parameters in carbon materials, the methods applied, and the respective standards describing them. Feel free to get more detailed information from the corresponding and linked Metrohm application documents. Missing your application? Contact your local Metrohm organization to discuss possible solutions.

Material	Parameter	Standard	Analysis technique	Application document
Graphene	Structural properties (crystal defects, domain and flake size, number of layers, stacking angle)	ISO/TR 19733, ASTM E3220, ISO/TS 21356-1	Raman spectroscopy	410000059
	Water content		Karl Fischer titration	
	Water soluble anions	IEC TS 62607-6-30, GB/T 41068	Ion chromatography	
	Oxygen content (Boehm titration)	ISO/TR 19733, IEC TS 62607-6-13, GB/T 38114	Titration	AN-T-226
	Electrochemical evaluation of graphene and graphene oxide (e.g., capacitance)		Electrochemistry	AN-EC-007, AN-EC-009, AN-EC-012, AN-SC-001, AN-EC-031
	Characterization in dependence of applied potential		Raman spectroelectrochemistry	AN-RA-002
	Sulfur, fluorine, chlorine, and bromine	GB/T 41067	Combustion ion chromatography (CIC)	
Carbon nanotubes (SWCNT and MWCNT)	Disorder of crystal structure, dimensions of nanotubes	ISO/TR 10929 (MWCNT)	Raman spectroscopy	410000059
	Characterization as a function of applied potential		Raman spectroelectrochemistry	AN-RA-002, AN-RA-005, AN-RA-009
	Water content (of suspensions)	ISO/TS 19808	Karl Fischer titration	
	Oxygen content (Boehm titration)		Titration	AN-T-226
	pH value of suspensions	ISO/TS 19808	pH measurement	
Graphite	Characterization	ISO/TS 21356-1	Raman spectroscopy	410000059
	Characterization in dependence of applied potential		Raman spectroelectrochemistry	AN-RA-002
	Intercalation and de-intercalation of lithium		Electrochemistry	WP-052
	Water content		Karl Fischer titration	AB-434
	Sulfur	ASTM C816	Titration	
	Oxygen content (Boehm Titration)		Titration	AN-T-226
Carbon black (amorphous carbon)	Characterization (D- and G- bands)	ASTM E3220	Raman spectroscopy	410000002, 410000059
	Electrochemical characterization		Electrochemistry	AN-EC-008
	Iodine adsorption number (IAN)	ASTM D1510	Titration	AN-T-176
	Water content		Karl Fischer titration	AB-434
	pH value of suspension	ASTM D1512, ISO 787-9, GB/T 1717	pH measurement	AN-T-235
Hard carbon	Insertion and de-insertion of sodium ion		Electrochemistry	WP-052
	Water content		Karl Fischer titration	

Analysis techniques

RAMAN SPECTROSCOPY

Raman spectroscopy is ideally suited for the non-destructive characterization of carbon materials. Distinct bands are attributed to the composition, structure, and other important properties. Disorder and dimensions of carbon nanomaterials can be characterized by Raman spectroscopy. Furthermore, by combining Raman spectroscopy with electrochemical measurements, the changes of the carbon material structure as a function of various potentials can be investigated.



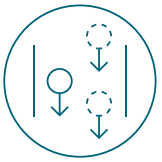
ELECTROCHEMISTRY – IDEAL FOR STUDYING THE ELECTROCHEMICAL PROPERTIES OF CARBON MATERIALS

Our specially designed potentiostats/galvanostats are used for the electrochemical characterization of carbon materials. Electrochemical measurements are based on a highly accurate control and measurements of voltage, current, electrical charge, or impedance. Hyphenated EC-Raman and EC-UV/VIS/NIR techniques are used to study the spectroelectrochemical properties of carbon materials.

TITRATION – SPECIFIC, ACCURATE, AND RELIABLE

Potentiometric titration is ideally suited for determining the oxygen content (Boehm titration) or the iodine adsorption number (IAN). It is an inexpensive method to determine functional groups on carbon materials. Furthermore, it can be automated to optimize efficiency in the laboratory.

Water can interfere in certain applications, e.g., lithium-ion batteries. Sensitive coulometric Karl Fischer titration is the ideal determination method for water content at trace levels in, e.g., nonaqueous carbon nanomaterial suspensions. For direct analysis of solids, the Karl Fischer oven method can be applied, where residual moisture in the sample is evaporated and transferred to the titration cell.



Ion chromatography (IC) is an efficient and precise multi-parameter method to quantify anions and cations after extraction from carbon materials.