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**Nanotechnologies — Measurement  
technique matrix for the  
characterization of nano-objects**

*Nanotechnologies — Matrice de méthodes de mesure pour les nano-objets manufacturés*

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# Contents

	Page
<b>Foreword</b> .....	<b>viii</b>
<b>Introduction</b> .....	<b>ix</b>
<b>1 Scope</b> .....	<b>1</b>
<b>2 Normative references</b> .....	<b>1</b>
<b>3 Terms and definitions</b> .....	<b>1</b>
3.1 General terms.....	1
3.2 Nano-object parameters.....	2
<b>4 Parameters included in the matrix</b> .....	<b>3</b>
<b>5 Measurement techniques included in the matrix</b> .....	<b>5</b>
5.1 General.....	5
5.2 Acoustic spectroscopy.....	5
5.2.1 Description.....	5
5.2.2 Nano-object parameters.....	6
5.2.3 Advantages.....	6
5.2.4 Limitations.....	6
5.2.5 Measurand.....	6
5.2.6 Relevant standards.....	6
5.3 Analytical centrifugation (AC).....	6
5.3.1 Description.....	6
5.3.2 Nano-object parameters.....	7
5.3.3 Advantages.....	7
5.3.4 Limitations.....	7
5.3.5 Measurand.....	7
5.3.6 Relevant standards.....	7
5.4 Electroacoustic spectroscopy.....	7
5.4.1 Description.....	7
5.4.2 Nano-object parameters.....	7
5.4.3 Advantages.....	8
5.4.4 Limitations.....	8
5.4.5 Measurand.....	8
5.4.6 Relevant standards.....	8
5.5 Aerosol particle mass analyser (AMS).....	8
5.5.1 Description.....	8
5.5.2 Nano-object parameters.....	9
5.5.3 Advantages.....	9
5.5.4 Limitations.....	9
5.5.5 Measurand.....	9
5.5.6 Relevant standards.....	9
5.6 Auger electron spectroscopy (AES).....	9
5.6.1 Description.....	9
5.6.2 Nano-object parameters.....	9
5.6.3 Advantages.....	10
5.6.4 Limitations.....	10
5.6.5 Measurand.....	10
5.6.6 Relevant standards.....	10
5.7 Brunauer-Emmett-Teller (BET) method for physical adsorption — Surface area determination.....	10
5.7.1 Description.....	10
5.7.2 Nano-object parameters.....	11
5.7.3 Advantages.....	11
5.7.4 Limitations.....	11
5.7.5 Measurand.....	11

5.7.6	Relevant standards.....	11
5.8	Condensation particle counter (CPC).....	11
5.8.1	Description.....	11
5.8.2	Nano-object parameters.....	12
5.8.3	Advantages.....	12
5.8.4	Limitations.....	12
5.8.5	Measurand.....	12
5.8.6	Relevant standards.....	12
5.9	Differential mobility analysis system (DMAS).....	12
5.9.1	Description.....	12
5.9.2	Nano-object parameters.....	13
5.9.3	Advantages.....	13
5.9.4	Limitations.....	13
5.9.5	Measurand.....	13
5.9.6	Relevant standards.....	13
5.10	Differential scanning calorimetry (DSC).....	13
5.10.1	Description.....	13
5.10.2	Nano-object parameters.....	13
5.10.3	Advantages.....	13
5.10.4	Limitations.....	14
5.10.5	Measurand.....	14
5.10.6	Relevant standards.....	14
5.11	Dynamic light scattering (DLS).....	14
5.11.1	Description.....	14
5.11.2	Nano-object parameters.....	15
5.11.3	Advantages.....	15
5.11.4	Limitations.....	15
5.11.5	Measurand.....	15
5.11.6	Relevant standards.....	15
5.12	Electron energy loss spectroscopy (transmission EELS).....	16
5.12.1	Description.....	16
5.12.2	Nano-object parameters.....	16
5.12.3	Advantages.....	16
5.12.4	Limitations.....	16
5.12.5	Measurand.....	16
5.12.6	Relevant standards.....	16
5.13	Electrophoresis/capillary electrophoresis.....	16
5.13.1	Description.....	16
5.13.2	Nano-object parameters.....	18
5.13.3	Advantages.....	18
5.13.4	Limitations.....	18
5.13.5	Measurands.....	18
5.13.6	Relevant standards.....	18
5.14	Energy dispersive X-ray spectrometry (EDS/EDX and WDS).....	18
5.14.1	Description.....	18
5.14.2	Nano-object parameters.....	18
5.14.3	Advantages.....	19
5.14.4	Limitations.....	19
5.14.5	Measurand.....	19
5.14.6	Relevant standards.....	19
5.15	Field flow fractionation (FFF).....	19
5.15.1	Description.....	19
5.15.2	Nano-object parameters.....	19
5.15.3	Advantages.....	20
5.15.4	Limitations.....	20
5.15.5	Measurand.....	20
5.15.6	Relevant standards.....	20
5.16	Fluorescence spectroscopy.....	20

5.16.1	Description	20
5.16.2	Nano-object parameters	20
5.16.3	Advantages	20
5.16.4	Limitations	21
5.16.5	Measurand	21
5.16.6	Relevant standards	21
5.17	Fourier transform infrared (FT-IR) spectroscopy and FT-IR imaging	21
5.17.1	Description	21
5.17.2	Nano-object parameters	21
5.17.3	Advantages	21
5.17.4	Limitations	22
5.17.5	Measurand	22
5.17.6	Relevant standards for FT-IR	22
5.18	Induced grating method (IG)	22
5.18.1	Description	22
5.18.2	Nano-object parameters	22
5.18.3	Advantages	22
5.18.4	Limitations	22
5.18.5	Measurand	23
5.18.6	Relevant standards	23
5.19	Inductively coupled plasma–mass spectrometry (ICP-MS) and single particle inductively coupled plasma–mass spectrometry (SP-ICP-MS)	23
5.19.1	Description	23
5.19.2	Nano-object parameters	23
5.19.3	Advantages	23
5.19.4	Limitations	23
5.19.5	Measurand	24
5.19.6	Relevant standards	24
5.19.7	Nano-hyphenated ICP/MS techniques	24
5.20	Laser diffraction	25
5.20.1	Description	25
5.20.2	Nano-object parameters	25
5.20.3	Advantages	25
5.20.4	Limitations	25
5.20.5	Measurand	25
5.20.6	Relevant standards	25
5.21	Liquid chromatography–mass spectrometry (LC-MS)	26
5.21.1	Description	26
5.21.2	Nano-object parameters	26
5.21.3	Advantages	26
5.21.4	Limitations	26
5.21.5	Measurand	26
5.21.6	Relevant standards	26
5.22	Particle tracking analysis (PTA)	26
5.22.1	Description	26
5.22.2	Nano-object parameters	27
5.22.3	Advantages	27
5.22.4	Limitations	27
5.22.5	Measurand	27
5.22.6	Relevant standards	28
5.23	Optical absorption spectroscopy (UV/Vis/NIR)	28
5.23.1	Description	28
5.23.2	Nano-object parameters	28
5.23.3	Advantages	28
5.23.4	Limitations	28
5.23.5	Measurand	29
5.23.6	Relevant standards for	29
5.24	Quartz crystal microbalance (QCM)	29

5.24.1	Description	29
5.24.2	Nano-object parameters	29
5.24.3	Advantages	29
5.24.4	Limitations	29
5.24.5	Measurand	29
5.24.6	Relevant standards	29
5.25	Raman spectroscopy/Raman imaging	30
5.25.1	Description	30
5.25.2	Nano-object parameters	30
5.25.3	Advantages	30
5.25.4	Limitations	30
5.25.5	Measurand	30
5.25.6	Relevant standards for Raman	30
5.26	Resonant mass measurement (RMM)	31
5.26.1	Description	31
5.26.2	Nano-object parameters	31
5.26.3	Advantages	31
5.26.4	Limitations	31
5.26.5	Measurand	31
5.26.6	Relevant standards	31
5.27	Scanning electron microscopy (SEM)	31
5.27.1	Description	31
5.27.2	Nano-objects parameters	32
5.27.3	Advantages	32
5.27.4	Limitations	32
5.27.5	Measurand	33
5.27.6	Relevant standards	33
5.28	Scanning probe microscopy (SPM)	33
5.28.1	Description	33
5.28.2	Nano-object parameters	34
5.28.3	Advantages	34
5.28.4	Limitations	34
5.28.5	Measurand(s)	35
5.28.6	Relevant standards	35
5.29	Secondary ion mass spectrometry (SIMS) and Time of Flight SIMS (TOF-SIMS)	35
5.29.1	Description	35
5.29.2	Nano-object parameters	35
5.29.3	Advantages	35
5.29.4	Limitations	36
5.29.5	Measurand	36
5.29.6	Relevant standards	36
5.30	Small angle X-ray scattering (SAXS)	36
5.30.1	Description	36
5.30.2	Nano-object parameters	36
5.30.3	Advantages	37
5.30.4	Limitations	37
5.30.5	Measurand	37
5.30.6	Relevant standards	38
5.31	Static light scattering (SLS) and static multiple light scattering (SMLS)	38
5.31.1	Description	38
5.31.2	Nano-object parameters	38
5.31.3	Advantages	38
5.31.4	Limitations	39
5.31.5	Measurands (SLS)	39
5.31.6	Measurands (SMLS)	39
5.31.7	Relevant standards	39
5.32	Single particle light interaction methods	39
5.32.1	Description	39

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5.32.2	Nano-object parameters.....	40
5.32.3	Advantages.....	40
5.32.4	Limitations.....	40
5.32.5	Measurand.....	40
5.32.6	Relevant standards.....	40
5.33	Thermogravimetric analysis (TGA).....	40
5.33.1	Description.....	40
5.33.2	Nano-object parameters.....	40
5.33.3	Advantages.....	40
5.33.4	Limitations.....	41
5.33.5	Measurand.....	41
5.33.6	Relevant standards.....	41
5.33.7	Hyphenated TGA techniques.....	41
5.34	Transmission electron microscopy (TEM).....	41
5.34.1	Description.....	41
5.34.2	Nano-object parameters.....	41
5.34.3	Advantages.....	42
5.34.4	Limitations.....	42
5.34.5	Measurand.....	42
5.34.6	Relevant standards.....	42
5.35	X-ray diffraction (XRD).....	43
5.35.1	Description.....	43
5.35.2	Nano-object parameters.....	43
5.35.3	Advantages.....	43
5.35.4	Limitations.....	43
5.35.5	Measurand.....	43
5.35.6	Relevant standards.....	43
5.36	X-ray photoelectron spectroscopy (XPS).....	44
5.36.1	Description.....	44
5.36.2	Nano-object parameters.....	44
5.36.3	Advantages.....	44
5.36.4	Limitations.....	44
5.36.5	Measurand.....	44
5.36.6	Relevant standards.....	44
<b>Annex A (informative) Sample separation/preparation .....</b>		<b>46</b>
<b>Bibliography .....</b>		<b>49</b>

## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

The committee responsible for this document is ISO/TC 229, *Nanotechnologies*.

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## Introduction

This document connects the nano-object parameters that most commonly need to be measured with corresponding measurement techniques. This document will be a useful tool for nanotechnology interested parties to rapidly identify relevant information for measuring nano-objects. The common nano-object parameters are listed along the top row of the Quick-Use-Matrix (see [Table 1](#)). If a measurement technique listed in the first column of the matrix is applicable, the box in the matrix will be marked. Once a measurement technique of interest is identified, it is recommended that the reader then enter this document's body of text (see [Clause 5](#)), where you will find an alphabetical listing of the measurement techniques and descriptions of the advantages, limitations, relevant standards, measurand(s), and applicable nano-object parameters of each technique.

As scientific advances are made and additional commercial measurement techniques become available, this document will be periodically reviewed and updated to maintain its relevance.

Many of the techniques listed in this document have not been validated through round-robin testing or any other means for the measurement of nano-objects. This document is intended as a starting point and resource to help identify potentially useful and relevant techniques; it is not an exhaustive or primary source. It is recommended that once a technique has been identified, the reader refers to relevant international standards and conducts a literature search for similar or comparable applications. Other sources of information include instrument manufacturer's applications notes and technical literature.

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# Nanotechnologies — Measurement technique matrix for the characterization of nano-objects

## 1 Scope

This document provides a matrix that guides users to commercially available techniques relevant to the measurements of common physiochemical parameters for nano-objects. Some techniques are also applicable to nanostructured materials.

NOTE Guidance on sample separation and preparation is given in [Annex A](#).

## 2 Normative references

There are no normative references in this document.

## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/TS 80004-1, ISO/TS 80004-6 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at <http://www.electropedia.org/>

— ISO Online browsing platform: available at <http://www.iso.org/obp>

### 3.1 General terms

#### 3.1.1

##### **dispersion**

heterogeneous system in which a finely divided material is distributed in another material

[SOURCE: ISO 472:2013, 2.288]

#### 3.1.2

##### **measurand**

quantity intended to be measured

[SOURCE: ISO Guide 99:2007, 2.3]

#### 3.1.3

##### **nano-object**

discrete piece of material with one, two or three external dimensions in the nanoscale

Note 1 to entry: The second and third external dimensions are orthogonal to the first dimension and to each other.

[SOURCE: ISO/TS 80004-2:2015, 2.2]

#### 3.1.4

##### **nanostructured material**

material having internal or surface structure in the nanoscale

Note 1 to entry: If external dimensions are in the nanoscale, the term *nano-object* ([3.1.3](#)) is recommended.

[SOURCE: ISO/TS 80004-4:2011, 2.11]

## 3.2 Nano-object parameters

### 3.2.1

#### **chemical composition**

identity and possible quantification of a material's composite parts and its impurities

### 3.2.2

#### **concentration**

content of nano-objects in a sample, quantified as number, area, volume or mass content

Note 1 to entry: Transformation calculation from one type of quantity to another (e.g. number to volume) requires the knowledge of the complete particle size distribution and the assumption of a size-independent shape, porosity or density<sup>[6]</sup>.

### 3.2.3

#### **crystal property**

effect due to the presence of three-dimensional order at the level of molecular dimensions

Note 1 to entry: See Reference <sup>[1]</sup>.

### 3.2.4

#### **electrokinetic potential**

difference in electric potential between that at the slipping plane and that of the bulk liquid

Note 1 to entry: See Reference <sup>[7]</sup>.

Note 2 to entry: Electrokinetic potential is expressed in volts.

Note 3 to entry: Often called "zeta potential"

### 3.2.5

#### **shape**

external geometric form of a particle

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Note 1 to entry: See Reference <sup>[8]</sup>.

Note 2 to entry: For quantitative description by macroshape, mesoshape or microshape descriptors, see Reference <sup>[9]</sup>.

### 3.2.6

#### **size**

linear dimensions of a particle determined by a specified measurement method and under specified measurement conditions

Note 1 to entry: See Reference <sup>[10]</sup>.

Note 2 to entry: Different methods of analysis are based on the measurement of different physical properties. Independent of the particle property actually measured, the particle size is reported as a linear dimension, e.g. as the equivalent spherical diameter.

Note 3 to entry: Examples of size descriptors are those based at the opening of a sieve or a statistical diameter, e.g. the Feret diameter, measured by image analysis.

Note 4 to entry: In ISO 9276-1, the symbol  $x$  is used to denote the particle size. However, it is recognized that the symbol  $d$  is also widely used to designate these values. Therefore, the symbol  $x$  can be replaced by  $d$ .

### 3.2.7

#### **particle size distribution**

cumulative distribution of particle concentration as a function of particle size

[SOURCE: ISO 14644-1:2015, 3.2.4]

Note 1 to entry: Particle size distribution is of statistical nature so it can be expressed as a function of particle size<sup>[11]</sup>.

Note 2 to entry: The type of quantity (number, area, volume or mass) as well as the measurand, the measured equivalent spherical diameter, shall be indicated.

Note 3 to entry: Particle size distribution can be expressed as cumulative distribution or a distribution density (distribution of the fraction of material in a size class, divided by the width of that class).

### 3.2.8

#### surface area

extent of available surface area as determined by given method under stated conditions

Note 1 to entry: See Reference [12].

Note 2 to entry: Surface area is the quantity of accessible surface of a sample when exposed to either gaseous or liquid adsorbate phase. Surface area is conventionally expressed as a mass-specific surface area or as volume-specific surface area where the total quantity of area has been normalized either to the sample's mass or volume[13].

## 4 Parameters included in the matrix

Several comprehensive literature searches, input from ISO/TC 229 experts, and a review of current ISO work have identified frequently sought nano-object parameters that are listed across the top of the Quick-Use-Matrix (see Table 1). The parameters listed from left to right are in alphabetical order. A single technique alone often cannot provide sufficient information about all parameters of interest for a particular nano-object under study, nor is one technique likely to fully capture relevant information for a single parameter. Therefore, when available, it is recommended that more than one technique should be used for any parameter investigation.

Table 1 — Quick-Use-Matrix<sup>[4]</sup>

Technique	Acronym	Chemical composition	Concentration	Crystal properties	Electrokinetic potential	Shape	Size	Size distribution	Surface area
Acoustic spectroscopy			+				+	+	
Analytical centrifugation	AC							+	
Aerosol particle mass analyser	AMS		+				+		
Auger electron spectroscopy (scanning)	AES	+	+			+	+		
Brunauer-Emmett-Teller	BET								+
Condensation particle counter	CPC		+						
Differential mobility analysis system <sup>a</sup>	DMAS		+				+	+	
Differential scanning calorimetry	DSC	+							
Dynamic light scattering <sup>b</sup>	DLS						+	+	
Electroacoustic spectroscopy					+				

<sup>a</sup> Requires a special detector or additional instrumentation to obtain the desired parameter.

<sup>b</sup> Light scattering technique.

Table 1 (continued)

Technique	Acronym	Chemical composition	Concentration	Crystal properties	Electrokinetic potential	Shape	Size	Size distribution	Surface area
Electron energy loss spectroscopy <sup>a</sup>	EELS	+							
Electrophoresis/capillary electrophoresis					+				
EM based X-ray spectrometry <sup>a</sup>	EDX/EDS/WDS	+							
Field flow fractionation <sup>a</sup>	FFF	+	+				+	+	
Fluorescence spectroscopy	FL		+						
Fourier transform infrared spectroscopy/imaging	FTIR	+							
Induced grating method	IG						+	+	
Inductively coupled plasma-mass spectrometry and single particle ICP-MS	ICP-MS	+	+				+	+	
Laser diffraction <sup>b</sup>							+	+	
Liquid chromatography-mass spectrometry	LC-MS	+	+						
Particle tracking analysis	PTA				+		+	+	
Optical absorption spectroscopy	UV/Vis/NIR	+	+				+		
Quartz microbalances	QCM						+		
Raman spectroscopy/imaging		+		+					
Resonant mass measurement	RMM						+	+	
Scanning electron microscopy <sup>a</sup>	SEM	+		+		+	+	+	
Scanning probe microscopy	SPM/AFM					+	+	+	
Secondary ion mass spectrometry	SIMS		+						
Small angle X-ray scattering	SAXS					+	+	+	

<sup>a</sup> Requires a special detector or additional instrumentation to obtain the desired parameter.

<sup>b</sup> Light scattering technique.

Table 1 (continued)

Technique	Acronym	Chemical composition	Concentration	Crystal properties	Electrokinetic potential	Shape	Size	Size distribution	Surface area
Static light scattering <sup>b</sup>	SLS/SMLS		+				+		
Single particle light interaction methods <sup>b</sup>			+				+	+	
Thermogravimetric analysis	TGA	+							
Transmission electron microscopy <sup>a</sup>	TEM	+		+		+	+	+	
X-ray diffraction	XRD			+			+		
X-ray photoelectron spectroscopy	XPS	+	+						
<sup>a</sup> Requires a special detector or additional instrumentation to obtain the desired parameter.									
<sup>b</sup> Light scattering technique.									

## 5 Measurement techniques included in the matrix

### 5.1 General

In the following subclauses, measurement techniques are listed in alphabetical order (with some exceptions where similar techniques are grouped together). Included under each technique are the nano-object parameters that can be measured by the technique and a listing of the technique's advantages, limitations, measurands, and relevant standards. Generally, a single technique cannot provide characterization of all nano-object parameters of interest. Also, a technique may be useful to determine other parameters not listed. For comprehensive analysis of a single parameter, use of multiple techniques, where applicable, is highly recommended.

In some cases, there are multiple techniques that share a similar underlying theory of operation or physical phenomenon, but which have differences that make them uniquely applicable to different types of materials and measurement conditions. For example, different electromagnetic scattering techniques are better suited for the analysis of different materials (e.g. metals, polymers or refractories) or materials in different states (e.g. suspended in a liquid or incorporated into a solid matrix).

### 5.2 Acoustic spectroscopy

#### 5.2.1 Description

The basic concept is to measure the frequency-dependent attenuation or velocity of ultrasound as it propagates through a heterogeneous sample, e.g. colloids, dispersions and emulsions. There are two main types of vibrations: free and forced. Free vibrations are the natural or normal modes of vibration for a substance. Forced vibrations are caused by some sort of excitation to make the analyte resonate beyond its normal modes.

Both acoustic and electroacoustic spectroscopies (see 5.4) are linked to a sound propagation through a heterogeneous system such as a suspension or an emulsion. An acoustic spectrometer measures only the changes in the properties of the sound wave, whereas an electroacoustic spectrometer deals with connection between electrodynamic phenomena and the sound wave pressure field. Acoustic and electroacoustic spectroscopies are independent methods because the attenuation has little effect