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Nanotechnologies — Vocabulary —

Part 6: Nano-object characterization

Nanotechnologies — Vocabulaire —

Partie 6: Caractérisation des nano-objets

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

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Foreword

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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).

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This second edition cancels and replaces the first edition (ISO/TS 80004-6:2013), which has been technically revised throughout.

A list of all parts in the ISO/TS 80004 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Measurement and instrumentation techniques have effectively opened the door to modern nanotechnology. Characterization is key to understanding the properties and function of all nano-objects.

Nano-object characterization involves interactions between people with different backgrounds and from different fields. Those interested in nano-object characterization might, for example, be materials scientists, biologists, chemists or physicists, and might have a background that is primarily experimental or theoretical. Those making use of the data extend beyond this group to include regulators and toxicologists. To avoid any misunderstandings, and to facilitate both comparability and the reliable exchange of information, it is essential to clarify the concepts, to establish the terms for use and to establish their definitions.

The terms are classified under the following broad headings:

— Clause 3: General terms;

— Clause 4: Terms related to size and shape measurement;

— Clause 5: Terms related to chemical analysis;

— Clause 6: Terms related to measurement of other properties.

These headings are intended as a guide only, as some techniques can determine more than one property. Subclause 4.1 lists the overarching measurands that apply to the rest of Clause 4. Other measurands are more technique-specific and are placed in the text adjacent to the technique.

It should be noted that most techniques require analysis in a non-native state and involve sample preparation, e.g. placing the nano-objects on a surface or placing them in a specific fluid or vacuum. This could change the nature of the nano-objects.

The order of the techniques in this document should not be taken to indicate a preference and the techniques listed in this document are not intended to be exhaustive. Equally, some of the techniques listed in this document are more popular than others in their usage in analysing certain properties of nano-objects. Table 1 lists alphabetically the common techniques for nano-object characterization.

Subclause 4.5 provides definitions of microscopy methods and related terms. When abbreviated terms are used, note that the final “M”, given as “microscopy”, can also mean “microscope” depending on the context. For definitions relating to the microscope, the word “method” can be replaced by the word “instrument” where that appears.

Clause 5 provides definitions of terms related to chemical analysis. For these abbreviated terms, note that the final “S”, given as “spectroscopy”, can also mean “spectrometer” depending on the context. For definitions relating to the spectrometer, the word “method” can be replaced by the word “instrument” where that appears.

This document is intended to serve as a starting reference for the vocabulary that underpins measurement and characterization efforts in the field of nanotechnologies.

Table 1 — Alphabetical list of the common techniques for nano-object characterization

Property	Common techniques
Size	centrifugal liquid sedimentation (CLS) atomic-force microscopy (AFM) differential mobility analysing system (DMAS) dynamic light scattering (DLS) variants of inductively coupled plasma mass spectrometry (ICP-MS) particle tracking analysis (PTA) scanning electron microscopy (SEM) small-angle X-ray scattering (SAXS) transmission electron microscopy (TEM)
Shape	atomic-force microscopy (AFM) scanning electron microscopy (SEM) transmission electron microscopy (TEM)
Surface area	Brunauer–Emmett–Teller (BET) method
"Surface" chemistry	Raman spectroscopy secondary-ion mass spectrometry (SIMS) X-ray photoelectron spectroscopy (XPS)
Chemistry of the "bulk" sample	energy-dispersive X-ray spectroscopy (EDX) inductively coupled plasma mass spectrometry (ICP-MS) nuclear magnetic resonance (NMR) spectroscopy
Crystallinity	selected area electron diffraction (SAED) X-ray diffraction (XRD)
Electrokinetic potential in suspensions	electrophoretic mobility

Nanotechnologies — Vocabulary —

Part 6: Nano-object characterization

1 Scope

This document defines terms related to the characterization of nano-objects in the field of nanotechnologies.

It is intended to facilitate communication between organizations and individuals in research, industry and other interested parties and those who interact with them.

2 Normative references

There are no normative references in this document.

3 Terms and definitions (General terms)

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

— ISO Online browsing platform: available at https://www.iso.org/obp

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

3.1
nanoscale
length range approximately from 1 nm to 100 nm

Note 1 to entry: Properties that are not extrapolations from a larger size are predominantly exhibited in this length range.

[SOURCE: ISO/TS 80004-1:2015, 2.1]

3.2
nano-object
discrete piece of material with one, two or three external dimensions in the *nanoscale* (3.1)

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

[SOURCE: ISO/TS 80004-1:2015, 2.5]

3.3
nanoparticle
nano-object (3.2) with all external dimensions in the *nanoscale* (3.1) where the lengths of the longest and the shortest axes of the nano-object do not differ significantly

Note 1 to entry: If the dimensions differ significantly (typically by more than three times), terms such as *nanofibre* (3.6) or *nanoplate* (3.4) may be preferred to the term “nanoparticle”.

[SOURCE: ISO/TS 80004-2:2015, 4.4]

3.4
nanoplate
nano-object (3.2) with one external dimension in the *nanoscale* (3.1) and the other two external dimensions significantly larger

Note 1 to entry: The larger external dimensions are not necessarily in the nanoscale.

Note 2 to entry: See 3.3, Note 1 to entry.

[SOURCE: ISO/TS 80004-2:2015, 4.6]

3.5
nanorod
solid *nanofibre* (3.6)

[SOURCE: ISO/TS 80004-2:2015, 4.7]

3.6
nanofibre
nano-object (3.2) with two external dimensions in the *nanoscale* (3.1) and the third dimension significantly larger

Note 1 to entry: The largest external dimension is not necessarily in the nanoscale.

Note 2 to entry: The terms “nanofibril” and “nanofilament” can also be used.

Note 3 to entry: See 3.3, Note 1 to entry.

[SOURCE: ISO/TS 80004-2:2015, 4.5]

3.7
nanotube
hollow *nanofibre* (3.6)

[SOURCE: ISO/TS 80004-2:2015, 4.8]

3.8
quantum dot
nanoparticle (3.3) or region which exhibits quantum confinement in all three spatial directions

[SOURCE: ISO/TS 80004-12:2016, 4.1, modified — Note 1 to entry has been deleted.]

3.9
particle
minute piece of matter with defined physical boundaries

Note 1 to entry: A physical boundary can also be described as an interface.

Note 2 to entry: A particle can move as a unit.

Note 3 to entry: This general particle definition applies to *nano-objects* (3.2).

[SOURCE: ISO/TS 80004-2:2015, 3.1]

3.10
agglomerate
collection of weakly or medium strongly bound *particles* (3.9) where the resulting external surface area is similar to the sum of the surface areas of the individual components

Note 1 to entry: The forces holding an agglomerate together are weak forces, for example van der Waals forces or simple physical entanglement.

Note 2 to entry: Agglomerates are also termed “secondary particles” and the original source particles are termed “primary particles”.

[SOURCE: ISO/TS 80004-2:2015, 3.4]

3.11
aggregate
particle (3.9) comprising strongly bonded or fused particles where the resulting external surface area is significantly smaller than the sum of surface areas of the individual components

Note 1 to entry: The forces holding an aggregate together are strong forces, for example covalent or ionic bonds, or those resulting from sintering or complex physical entanglement, or otherwise combined former primary particles.

Note 2 to entry: Aggregates are also termed "secondary particles" and the original source particles are termed "primary particles".

[SOURCE: ISO/TS 80004-2:2015, 3.5]

3.12
aerosol
system of solid and/or liquid *particles* (3.9) suspended in gas

[SOURCE: ISO 15900:2020, 3.1]

3.13
suspension
heterogeneous mixture of materials comprising a liquid and a finely dispersed solid material

[SOURCE: ISO 4618:2014, 2.246]

3.14
dispersion
multi-phase system in which discontinuities of any state (solid, liquid or gas: discontinuous phase) are distributed in a continuous phase of a different composition or state

Note 1 to entry: This term also refers to the act or process of producing a dispersion; in this context the term "dispersion process" should be used.

Note 2 to entry: If solid *particles* (3.9) are distributed in a liquid, the dispersion is referred to as a *suspension* (3.13). If the dispersion consists of two or more immiscible liquid phases, it is termed an "emulsion". A suspoemulsion consists of both solid and liquid phases distributed in a continuous liquid phase.

[SOURCE: ISO/TR 13097:2013, 2.5, modified — In the definition, "in general, microscopic" has been deleted and "distributed" has replaced "dispersed". Notes 1 and 2 to entry have replaced the original Note 1 to entry.]

4 Terms related to size and shape measurement

4.1 Terms related to measurands for size and shape

4.1.1
particle size
linear dimension of a *particle* (3.9) determined by a specified measurement method and under specified measurement conditions

Note 1 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 can be reported as a linear dimension, e.g. as the equivalent spherical diameter.

4.1.2
particle size distribution
distribution of the quantity of *particles* (3.9) as a function of *particle size* (4.1.1)

Note 1 to entry: Particle size distribution may 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).

Note 2 to entry: The quantity can be, for example, number, mass or volume based.

4.1.3
particle shape
external geometric form of a *particle* (3.9)

[SOURCE: ISO 3252:2019, 3.1.59, modified — "powder" has been deleted before "particle".]

4.1.4
aspect ratio
ratio of length of a *particle* (3.9) to its width

[SOURCE: ISO 14966:2019, 3.7]

4.1.5
equivalent diameter
diameter of a sphere that produces a response by a given particle-size measurement method that is equivalent to the response produced by the *particle* (3.9) being measured

Note 1 to entry: Physical properties are, for example, the same settling velocity or electrolyte solution displacing volume or projection area under a microscope. The physical property to which the equivalent diameter refers should be indicated using a suitable subscript (see ISO 9276-1:1998), e.g. subscript "V" for equivalent volume diameter and subscript "S" for equivalent surface area diameter.

Note 2 to entry: For discrete-particle-counting, light-scattering instruments, an equivalent optical diameter is used.

Note 3 to entry: Other parameters, e.g. the effective density of the particle in a fluid, are used for the calculation of the equivalent diameter such as Stokes diameter or sedimentation equivalent diameter. The parameters used for the calculation should be reported additionally.

Note 4 to entry: For inertial instruments, the aerodynamic diameter is used. Aerodynamic diameter is the diameter of a sphere of density 1 000 kg m^{-3} that has the same settling velocity as the particle in question.

4.2 Terms related to scattering techniques

4.2.1
radius of gyration
measure of the distribution of mass about a chosen axis, given as the square root of the moment of inertia about that axis divided by the mass

Note 1 to entry: For *nano-object* (3.2) characterization, physical methods that measure radius of gyration to determine *particle size* (4.1.1) include static light scattering, *small-angle neutron scattering* (4.2.2) and *small-angle X-ray scattering* (4.2.4).

[SOURCE: ISO 14695:2003, 3.4, modified — Note 1 to entry has been added.]

4.2.2
small-angle neutron scattering
SANS
method in which a beam of neutrons is scattered from a sample and the scattered neutron intensity is measured for small angle deflection

Note 1 to entry: The scattering angle is usually between 0,5° and 10° in order to study the structure of a material on the length scale of approximately 1 nm to 200 nm. The method provides information on the sizes of the *particles* (3.9) and, to a limited extent, the shapes of the particles dispersed in a homogeneous medium.

4.2.3
neutron diffraction
application of elastic neutron scattering for the determination of the atomic or magnetic structure of matter

Note 1 to entry: The neutrons emerging from the experiment have approximately the same energy as the incident neutrons. A diffraction pattern is formed that provides information on the structure of the material.

4.2.4
small-angle X-ray scattering
SAXS
method in which the elastically scattered intensity of X-rays is measured for small-angle deflections

Note 1 to entry: The angular scattering is usually measured within the range 0,1° to 10°. This provides structural information on macromolecules as well as periodicity on length scales typically larger than 5 nm and less than 200 nm for ordered or partially ordered systems.

[SOURCE: ISO 18115-1:2013, 3.18, modified — Notes 2 and 3 to entry have been deleted.]

4.2.5
light scattering
change in propagation of light at the interface of two media having different optical properties

4.2.6
hydrodynamic diameter
equivalent diameter (4.1.5) of a *particle* (3.9) in a liquid having the same diffusion coefficient as a spherical particle with no boundary layer in that liquid

Note 1 to entry: In practice, *nanoparticles* (3.3) in solution can be non-spherical, dynamic and solvated.

Note 2 to entry: A particle in a liquid will have a boundary layer. This is a thin layer of fluid or adsorbates close to the solid surface, within which shear stresses significantly influence the fluid velocity distribution. The fluid velocity varies from zero at the solid surface to the velocity of free stream flow at a certain distance away from the solid surface.

4.2.7
dynamic light scattering
DLS
photon correlation spectroscopy
PCS
DEPRECATED: quasi-elastic light scattering
DEPRECATED: QELS
method in which *particles* (3.9) in a liquid *suspension* (3.13) are illuminated by a laser and the time dependant change in intensity of the scattered light due to Brownian motion is used to determine *particle size* (4.1.1)

Note 1 to entry: Analysis of the time-dependent intensity of the scattered light can yield the translational diffusion coefficient and hence the particle size as the *hydrodynamic diameter* (4.2.6) using the Stokes–Einstein relationship.

Note 2 to entry: The analysis is applicable to *nanoparticles* (3.3) as the size of particles detected is typically in the range 1 nm to 6 000 nm. The upper limit is due to limited Brownian motion and sedimentation.

Note 3 to entry: DLS is typically used in dilute suspensions where the particles do not interact amongst themselves.

4.2.8
nanoparticle tracking analysis
NTA
particle tracking analysis
PTA
method in which *particles* (3.9) undergoing Brownian and/or gravitational motion in a *suspension* (3.13) are illuminated by a laser and the change in position of individual particles is used to determine *particle size* (4.1.1)

Note 1 to entry: Analysis of the time-dependent particle position yields the translational diffusion coefficient and hence the particle size as the *hydrodynamic diameter* (4.2.6) using the Stokes-Einstein relationship.

Note 2 to entry: The analysis is applicable to *nanoparticles* (3.3) as the size of particles detected is typically in the range 10 nm to 2 000 nm. The lower limit requires particles with high refractive index and the upper limit is due to limited Brownian motion and sedimentation.

Note 3 to entry: NTA is often used to describe PTA. NTA is a subset of PTA since PTA covers larger range of particle sizes than *nanoscale* (3.1).

4.2.9
static multiple light scattering
SMLS
technique in which transmitted or backscattered light intensity is measured after multiple successive scattering events of incident light in a random scattering medium

[SOURCE: ISO/TS 21357:—[1)], 3.1]

4.3 Terms related to aerosol characterization

4.3.1
condensation particle counter
CPC
instrument that measures the *particle* (3.9) number concentration of an *aerosol* (3.12) using a condensation effect to increase the size of the aerosolized particles

Note 1 to entry: The sizes of particles detected are usually smaller than several hundred nanometres and larger than a few nanometres.

Note 2 to entry: A CPC is one possible detector suitable for use with a *differential electrical mobility classifier (DEMC)* (4.3.2).

Note 3 to entry: In some cases, a condensation particle counter may be called a “condensation nucleus counter (CNC)”.

[SOURCE: ISO/TS 12025:2012, 3.2.8, modified — Note 4 to entry has been deleted.]

4.3.2
differential electrical mobility classifier
DEMC
classifier able to select *aerosol* (3.12) *particles* (3.9) according to their electrical mobility and pass them to its exit

Note 1 to entry: A DEMC classifies aerosol particles by balancing the electrical force on each particle with its aerodynamic drag force in an electrical field. Classified particles are in a narrow range of electrical mobility determined by the operating conditions and physical dimensions of the DEMC, while they can have different sizes due to difference in the number of charges that they have.

[SOURCE: ISO 15900:2020, 3.11]

1) Under preparation. Stage at the time of publication: ISO/DTS 21357:2020.