TECHNICAL SPECIFICATION

ISO/TS 80004-6

First edition
2013-11-01

Nanotechnologies — Vocabulary —

Part 6: Nano-object characterization

Nanotechnologies — Vocabulaire —

Partie 6: Caractérisation d'un nano-objet

Reference number
ISO/TS 80004-6:2013(E)

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Published in Switzerland

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Foreword

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ISO/TS 80004-6 was prepared jointly by Technical Committee ISO/TC 229, *Nanotechnologies* and Technical Committee IEC/TC 113, *Nanotechnology standardization for electrical and electronic products and systems*. The draft was circulated for voting to the national bodies of both ISO and IEC.

Documents in the 80000 to 89999 range of reference numbers are developed by collaboration between ISO and IEC.

ISO/TS 80004 consists of the following parts, under the general title *Nanotechnologies — Vocabulary*:

— *Part 1: Core terms*

— *Part 3: Carbon nano-objects*

— *Part 4: Nanostructured materials*

— *Part 5: Nano/bio interface*

— *Part 6: Nano-object characterization*

— *Part 7: Diagnostics and therapeutics for healthcare*

— *Part 8: Nanomanufacturing processes*

The following parts are under preparation:

— *Part 2: Nano-objects: Nanoparticle, nanofibre and nanoplate*[1)]

— *Part 9: Nano-enabled electrotechnical products and systems*

— *Part 10: Nano-enabled photonic components and systems*

— *Part 11: Nanolayer, nanocoating, nanofilm, and related terms*

1) Revision of ISO/TS 27687:2008, *Nanotechnologies — Terminology and definitions for nano-objects — Nanoparticle, nanofibre and nanoplate*.

— *Part 12: Quantum phenomena in nanotechnology*

Graphene and other two dimensional materials will form the subject of a future Part 13.

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 2: General terms

— Clause 3: Terms related to size and shape measurement

— Clause 4: Terms related to chemical analysis

— Clause 5: Terms related to measurement of other properties

These headings are intended as guide only, as some techniques can determine more than one property. Subclause 3.1 lists the overarching measurands that apply to the rest of Clause 3. 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, for example placing the nano-objects on a surface or placing it 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 main current techniques for nano-object characterization.

Table 1 — Alphabetical list of main current techniques for nano-object characterization

Property	Current main techniques
Size	atomic force microscopy (AFM), centrifugal liquid sedimentation (CLS), differential mobility analysing system (DMAS), dynamic light scattering (DLS), scanning electron microscopy (SEM), particle tracking analysis (PTA), 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	secondary ion mass spectrometry (SIMS), X-ray photoelectron spectroscopy (XPS)
Chemistry of the 'bulk' sample	inductively coupled plasma mass spectrometry (ICP-MS), nuclear magnetic resonance spectroscopy (NMR)
Charge in suspensions	zeta potential

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

Nanotechnologies — Vocabulary —

Part 6: Nano-object characterization

1 Scope

This Technical Specification lists terms and definitions relevant to the characterization of nano-objects.

2 General terms

2.1
nanoscale
size range from approximately 1 nm to 100 nm

Note 1 to entry: Properties that are not extrapolations from a larger size will typically, but not exclusively, be exhibited in this size range. For such properties the size limits are considered approximate.

Note 2 to entry: The lower limit in this definition (approximately 1 nm) is introduced to avoid single and small groups of atoms from being designated as *nano-objects* (2.2) or elements of nanostructures, which might be implied by the absence of a lower limit.

[SOURCE: ISO/TS 80004-1:2010, definition 2.1]

2.2
nano-object
material with one, two or three external dimensions in the *nanoscale* (2.1)

Note 1 to entry: Generic term for all discrete nanoscale objects.

[SOURCE: ISO/TS 80004-1:2010, definition 2.5]

2.3
nanoparticle
nano-object (2.2) with all three external dimensions in the *nanoscale* (2.1)

Note 1 to entry: If the lengths of the longest to the shortest axes of the nano-object differ significantly (typically by more than three times), the terms *nanofibre* (2.6) or *nanoplate* (2.4) are intended to be used instead of the term nanoparticle.

[SOURCE: ISO/TS 27687:2008, definition 4.1]

2.4
nanoplate
nano-object (2.2) with one external dimension in the *nanoscale* (2.1) and the two other external dimensions significantly larger

Note 1 to entry: The smallest external dimension is the thickness of the nanoplate.

Note 2 to entry: The two significantly larger dimensions are considered to differ from the nanoscale dimension by more than three times.

Note 3 to entry: The larger external dimensions are not necessarily in the nanoscale.

[SOURCE: ISO/TS 27687:2008, definition 4.2]

2.5
nanorod
solid *nanofibre* (2.6)

[SOURCE: ISO/TS 27687:2008, definition 4.5]

2.6
nanofibre
nano-object (2.2) with two similar external dimensions in the *nanoscale* (2.1) and the third dimension significantly larger

Note 1 to entry: A nanofibre can be flexible or rigid.

Note 2 to entry: The two similar external dimensions are considered to differ in size by less than three times and the significantly larger external dimension is considered to differ from the other two by more than three times.

Note 3 to entry: The largest external dimension is not necessarily in the nanoscale.

[SOURCE: ISO/TS 27687:2008, definition 4.3]

2.7
nanotube
hollow *nanofibre* (2.6)

[SOURCE: ISO/TS 27687:2008, definition 4.4]

2.8
quantum dot
crystalline *nanoparticle* (2.3) that exhibits size-dependent properties due to quantum confinement effects on the electronic states

[SOURCE: ISO/TS 27687:2008, definition 4.7]

2.9
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* (2.2).

[SOURCE: ISO 14644-6:2007, definition 2.102 and ISO/TS 27687:2008, definition 3.1]

2.10
agglomerate
collection of weakly bound *particles* (2.9) or *aggregates* (2.11) or mixtures of the two 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 27687:2008, definition 3.2]

2.11
aggregate
particle (2.9) comprising strongly bonded or fused particles where the resulting external surface area may be significantly smaller than the sum of calculated surface areas of the individual components

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

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

[SOURCE: ISO/TS 27687:2008, definition 3.3]

2.12
aerosol
system of solid or liquid *particles* (2.9) suspended in gas

[SOURCE: ISO 15900:2009, definition 2.1]

2.13
suspension
heterogeneous mixture of materials comprising a liquid and a finely dispersed solid material

[SOURCE: ISO 4618:—, definition 2.243]

3 Terms related to size and shape measurement

3.1 Terms related to measurands for size and shape

3.1.1
particle size
linear dimension of a *particle* (2.9) determined by a specified measurement method and under specified measurement conditions

[SOURCE: ISO 26824:2013, definition 1.5]

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.

3.1.2
particle size distribution
distribution of *particles* (2.9) as a function of *particle size* (3.1.1)

[SOURCE: ISO 14644-1:1999, definition 2.2.4, modified]

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).

3.1.3
particle shape
external geometric form of a *particle* (2.9)

[SOURCE: ISO 3252:1999]

3.1.4
aspect ratio
ratio of length of a *particle* (2.9) to its width

[SOURCE: ISO 14966:2002, definition 2.8]

3.1.5
equivalent diameter
diameter of a sphere that produces a response by a given particle-sizing method, that is equivalent to the response produced by the *particle* (2.9) being measured

Note 1 to entry: The physical property to which the equivalent diameter refers is indicated using a suitable subscript (see ISO 9276-1:1998).

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

Note 3 to entry: Other material constants like density of the particle are used for the calculation of the equivalent diameter like Stokes diameter or sedimentation equivalent diameter. The material constants, 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 irregular particle.

[SOURCE: ISO/TS 27687:2008, A.3.3, modified]

3.2 Terms related to scattering techniques

3.2.1
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

[SOURCE: ISO 14695:2003, definition 3.4]

Note 1 to entry: For *nano-object* (2.2) characterization, physical methods that measure radius of gyration to determine *particle size* (3.1.1) include static light scattering, *small angle neutron scattering* (3.2.2) and *small angle X-ray scattering* (3.2.4).

3.2.2
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 1 nm to 100 nm. The method provides information on the sizes of the *particles* (2.9) and to a limited extent the shapes of the particles dispersed in homogeneous medium.

3.2.3
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.

3.2.4
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, definition 4.18]

3.2.5
light scattering
change in propagation of light at the interface of two media having different optical properties

[SOURCE: ISO 13320:2009, definition 3.1.17]

3.2.6
hydrodynamic diameter
equivalent diameter (3.1.5) of a *particle* (2.9) in a liquid having the same diffusion coefficient as the real particle in that liquid

3.2.7
dynamic light scattering
DLS
photon correlation spectroscopy
PCS
quasi-elastic light scattering
QELS
method in which *particles* (2.9) undergoing Brownian motion in a liquid *suspension* (2.13) are illuminated by a laser and the change in intensity of the scattered light is used to determine *particle size* (3.1.1)

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* (3.2.6) via the Stokes–Einstein relationship.

Note 2 to entry: The analysis is applicable to *nanoparticles* (2.3) as the size of particles detected is typically in the range 1 nm to 6000 nm. The upper limit is due to limited Brownian motion and sedimentation.

3.2.8
nanoparticle tracking analysis
NTA
particle tracking analysis
PTA

method where *particles* (2.9) undergoing Brownian motion in a liquid *suspension* (2.13) are illuminated by a laser and the change in position of individual particles is used to determine *particle size* (3.1.1)

Note 1 to entry: Analysis of the time-dependent position of individual particles by means of scattered light can yield the translational diffusion coefficient and hence the particle size as the *hydrodynamic diameter* (3.2.6) using the Stokes–Einstein relationship

Note 2 to entry: The analysis is applicable to *nanoparticles* (2.3) as the size of particles detected is typically in the range 10 nm to 2000 nm. The lower limit requires particles with high refractive index and the upper limit is due to limited Brownian motion and sedimentation.

3.3 Terms related to aerosol characterization

3.3.1
condensation particle counter
CPC
instrument that measures the *particle* (2.9) number concentration of an *aerosol* (2.12)

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)* (3.3.2).

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

[SOURCE: ISO 15900:2009, definition 2.5]

3.3.2
differential electrical mobility classifier
DEMC
classifier that is able to select *aerosol* (2.12)*particles* (2.9) 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 15900:2009, definition 2.7]

3.3.3
differential mobility analysing system
DMAS
system to measure the size distribution of submicrometre *aerosol* (2.12)*particles* (2.9) consisting of a *DEMC* (3.3.2), flow meters, a particle detector, interconnecting plumbing, a computer and suitable software

[SOURCE: ISO 15900:2009, definition 2.8]

3.3.4
Faraday-cup aerosol electrometer
FCAE
system designed for the measurement of electrical charges carried by *aerosol* (2.12)*particles* (2.9)

Note 1 to entry: A Faraday-cup aerosol electrometer consists of an electrically conducting and electrically grounded cup as a guard to cover the sensing element that includes aerosol filtering media to capture charged aerosol particles, an electrical connection between the sensing element and an electrometer circuit, and a flow meter.

[SOURCE: ISO 15900:2009, definition 2.12, modified]

3.4 Terms related to separation techniques

3.4.1
field flow fractionation
FFF
separation technique where a field is applied to a liquid *suspension* (2.13) passing along a narrow channel in order to cause separation of the *particles* (2.9) present in the liquid, dependent on their differing mobility under the force exerted by the field

Note 1 to entry: The field can be, for example, gravitational, centrifugal, a liquid flow, electrical or magnetic.

Note 2 to entry: Using a suitable detector after or during separation allows determination of the size and size distribution of *nano-objects* (2.2).

3.4.2
centrifugal liquid sedimentation
CLS
differential centrifugal sedimentation
DCS
method in which a sample is separated based on size and density using a rotating disc filled with a fluid containing a density gradient

Note 1 to entry: Depending on the density of the *particles* (2.9), the technique can measure *particle size* (3.1.1) and *particle size distribution* (3.1.2) between 2 nm and 10 µm and can resolve particles differing in size by less than 2 %.