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PD ISO/TS 80004-6:2013

BSI Standards Publication

Nanotechnologies — Vocabulary

Part 6: Nano-object characterization

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National foreword

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TECHNICAL SPECIFICATION

ISO/TS 80004-6

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Nanotechnologies — Vocabulary —

Part 6:
Nano-object characterization

Nanotechnologies — Vocabulaire —

Partie 6: Caractérisation d'un nano-objet

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Contents

Page

Foreword iv
Introduction vi
1 Scope 1
2 General terms 1
3 Terms related to size and shape measurement 3
3.1 Terms related to measurands for size and shape 3
3.2 Terms related to scattering techniques 4
3.3 Terms related to aerosol characterization 5
3.4 Terms related to separation techniques 6
3.5 Terms related to microscopy 7
3.6 Terms related to surface area measurement 10
4 Terms related to chemical analysis 11
5 Terms related to measurement of other properties 15
5.1 Terms related to mass measurement 15
5.2 Terms related to crystallinity measurement 16
5.3 Terms related to charge measurement in suspensions 16
Annex A (informative) **Index** 18
Bibliography 23

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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*

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

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— *Part 12: Quantum phenomena in nanotechnology*

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

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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.

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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]

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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]

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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]

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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]

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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]

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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 %.

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3.4.3
size-exclusion chromatography
SEC
liquid chromatographic technique in which the separation is based on the hydrodynamic volume of molecules eluting in a column packed with porous non-adsorbing material having pore dimensions that are similar in size to the molecules being separated

[SOURCE: ISO 16014-1:2012, definition 3.1]

Note 1 to entry: SEC can be coupled with a detector, for example *dynamic light scattering (DLS)* (3.2.7), for determination of the size and size distribution of the eluting species.

3.4.4
electrical zone sensing
Coulter counter
method for counting and sizing *particles* (2.9) in electrolytes by measuring a drop in electrical current as a particle passes through an aperture between two chambers

Note 1 to entry: The drop in current is proportional to the particle volume.

Note 2 to entry: The particles are driven through the aperture by pressure or an electric field.

Note 3 to entry: The aperture can be *nanoscale* (2.1) in size allowing the sizing of individual *nano-objects* (2.2).

3.5 Terms related to microscopy

The following are the definitions of microscopy methods and related terms. In the list below, note that the final “M” in the acronyms, given as “microscopy”, may also mean “microscope” depending on the context. For the definition relating to the microscope, replace the word “method” by the word “instrument” where that appears.

3.5.1
scanning probe microscopy
SPM
method of imaging surfaces by mechanically scanning a probe over the surface under study, in which the concomitant response of a detector is measured

[SOURCE: ISO 18115-2, definition 4.31]

Note 1 to entry: This generic term encompasses many methods including *atomic force microscopy (AFM)* (3.5.2), *scanning near field optical microscopy (SNOM)* (3.5.4), scanning ion conductance microscopy (SICM) and *scanning tunnelling microscopy (STM)* (3.5.3).

Note 2 to entry: The resolution varies from that of STM, where individual atoms can be resolved, to scanning thermal microscopy (SThM) in which the resolution is generally limited to around 1 µm.

3.5.2
atomic force microscopy
AFM
scanning force microscopy (deprecated)
SFM (deprecated)
method for imaging surfaces by mechanically scanning their surface contours, in which the deflection of a sharp tip sensing the surface forces, mounted on a compliant cantilever, is monitored

[SOURCE: ISO 18115-2, definition 4.3]

Note 1 to entry: AFM can provide a quantitative height image of both insulating and conducting surfaces.

Note 2 to entry: Some AFM instruments move the sample in the *x*-, *y*- and *z*-directions while keeping the tip position constant and others move the tip while keeping the sample position constant.

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Note 3 to entry: AFM can be conducted in vacuum, a liquid, a controlled atmosphere or air. Atomic resolution may be attainable with suitable samples, with sharp tips and by using an appropriate imaging mode.

Note 4 to entry: Many types of force can be measured, such as the normal forces or the lateral, friction or shear force. When the latter is measured, the technique is referred to as lateral, frictional or shear force microscopy. This generic term encompasses all of these types of force microscopy.

Note 5 to entry: AFMs can be used to measure surface normal forces at individual points in the pixel array used for imaging.

Note 6 to entry: For typical AFM tips with radii < 100 nm, the normal force should be less than about 0,1 µN, depending on the sample material, or irreversible surface deformation and excessive tip wear occurs.

3.5.3
scanning tunnelling microscopy
STM
SPM (3.5.1) mode for imaging conductive surfaces by mechanically scanning a sharp, voltage-biased, conducting probe tip over their surface, in which the data of the tunnelling current and the tip-surface separation are used in generating the image

Note 1 to entry: STM can be conducted in vacuum, a liquid or air. Atomic resolution can be achieved with suitable samples and sharp probes and can, with ideal samples, provide localized bonding information around surface atoms.

Note 2 to entry: Images can be formed from the height data at a constant tunnelling current or the tunnelling current at a constant height or other modes at defined relative potentials of the tip and sample.

Note 3 to entry: STM can be used to map the densities of states at surfaces or, in ideal cases, around individual atoms. The surface images can differ significantly, depending on the tip bias, even for the same topography.

[SOURCE: ISO 18115-2, definition 4.35]

3.5.4
near-field scanning optical microscopy
NSOM
scanning near-field optical microscopy
SNOM
method of imaging surfaces optically in transmission or reflection by mechanically scanning an optically active probe much smaller than the wavelength of light over the surface whilst monitoring the transmitted or reflected light or an associated signal in the near-field regime

Note 1 to entry: Topography is important and the probe is scanned at constant height. Usually the probe is oscillated in the shear mode to detect and set the height.

Note 2 to entry: Where the extent of the optical probe is defined by an aperture, the aperture size is typically in the range 10 nm to 100 nm, and this largely defines the resolution. This form of instrument is often called an aperture NSOM or aperture SNOM to distinguish it from a scattering NSOM or scattering SNOM (previously called apertureless NSOM or apertureless SNOM) although, generally, the adjective “aperture” is omitted. In the apertureless form, the extent of the optically active probe is defined by an illuminated sharp metal or metal-coated tip with a radius typically in the range 10 nm to 100 nm, and this largely defines the resolution.

Note 3 to entry: In addition to the optical image, NSOM can provide a quantitative image of the surface contours similar to that available in *AFM* (3.5.2) and allied scanning-probe techniques.

[SOURCE: ISO 18115-2, definition 4.18]

3.5.5
scanning electron microscopy
SEM
method that examines and analyses the physical information (such as secondary electron, backscattered electron, absorbed electron and X-ray radiation) obtained by generating electron beams and scanning the surface of the sample in order to determine the structure, composition and topography of the sample

[SOURCE: ISO 17751, definition 4.10, modified]

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3.5.6
transmission electron microscopy
TEM
method that produces magnified images or diffraction patterns of the sample by an electron beam which passes through the sample and interacts with it

[SOURCE: ISO 29301:2010, definition 3.37, modified]

3.5.7
scanning transmission electron microscopy
STEM
method that produces magnified images or diffraction patterns of the sample by a finely focused electron beam, scanned over the surface and which passes through the sample and interacts with it

Note 1 to entry: Typically uses an electron beam with a diameter of less than 1 nm.

Note 2 to entry: Provides high-resolution imaging of the inner microstructure and the surface of a thin sample [or small *particles* (2.9)], as well as the possibility of chemical and structural characterization of micrometre and sub-micrometre domains through evaluation of the X-ray spectra and the electron diffraction pattern.

[SOURCE: ISO/TS 10797, definition 3.10, modified]

3.5.8
low energy electron microscopy
LEEM
method that examines surfaces where images and/or diffraction patterns of the surfaces are formed by low-energy elastically backscattered electrons generated by a non-scanning electron beam

Note 1 to entry: The method is typically used for the imaging and analysis of very flat, clean surfaces.

Note 2 to entry: Low energy electrons have energies typically in the range 1 eV to 100 eV.

3.5.9
scanning ion microscopy
method in which an ion beam focused into a sub-nanometre scale spot is scanned over a surface to create an image

Note 1 to entry: A variety of different ion sources can be used for imaging, including helium, neon and argon.

3.5.10
confocal optical microscopy
method for microscopy in which, ideally, a point in the object plane is illuminated by a diffraction-limited spot of light, and light emanating from this point is focused upon and detected from an area smaller than the central area of the diffraction disc situated in the corresponding position in a subsequent field plane

Note 1 to entry: An image of an extended area is formed either by scanning the object, or by scanning the illuminated and detected spots simultaneously.

Note 2 to entry: The confocal principle leads to improved contrast and axial resolution by suppression of light from out-of-focus planes.

[SOURCE: ISO 10934-2:2007, definition 2.11, modified]

3.5.11
surface enhanced ellipsometric contrast microscopy
SEEC microscopy
method of optical imaging using the association of contrast-enhancing surfaces as sample slides and a reflected light optical microscope with crossed polarizers

Note 1 to entry: The contrast-enhancing slides are designed to become anti-reflecting when used in these conditions, leading to an increase in the axial sensitivity of the optical microscope by a factor of around 100.

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3.5.12
fluorescence
phenomenon in which absorption of light of a given wavelength by a substance is followed by the emission of light at a longer wavelength

[SOURCE: ISO 18115-2:2010, definition 6.52]

3.5.13
fluorescence microscopy
method of optical microscopy in which *fluorescence* (3.5.12) emitted by the sample is imaged

Note 1 to entry: A light source is required to excite fluorescence from the sample. This is typically at a shorter wavelength than the light used to form the image. Usually filters are used to separate the excitation and emission light.

Note 2 to entry: Fluorescence microscopy has many variants, including wide-field (epifluorescence), confocal, *total internal reflection fluorescence microscopy (TIRF)* (3.5.14) and *super-resolution microscopy* (3.5.15) methods.

Note 3 to entry: The fluorescence observed may be intrinsic to the sample or imparted by the use of fluorescent dyes.

3.5.14
total internal reflection fluorescence microscopy
TIRF microscopy
method in which *fluorescence* (3.5.12) is excited in a thin layer by an evanescent wave produced by total internal reflection

[SOURCE: ISO 10934-2:2007, definition 2.51, modified]

3.5.15
super-resolution microscopy
method of microscopy in which a spatial resolution finer than the limit normally imposed by diffraction is achieved

Note 1 to entry: The most common super-resolution microscopy approaches include *localization microscopy* (3.5.16), stimulated emission depletion (STED) microscopy and structured illumination microscopy (SIM).

Note 2 to entry: Most super-resolution microscopy techniques rely on *fluorescence* (3.5.12).

3.5.16
localization microscopy
method of *super-resolution microscopy* (3.5.15) in which the precise localization of individual (usually fluorescent) molecules is used to reconstruct an image

Note 1 to entry: Many different localization microscopy techniques have been developed. They differ mainly in the type of probes that are used. Examples include photoactivation localization microscopy (PALM) which relies on photoactivatable molecules (usually fluorescent proteins) and stochastic optical reconstruction microscopy (STORM) which relies on intermittent fluorescence (“blinking” or “switching”) of fluorophores.

Note 2 to entry: Typically, to achieve precise localization of fluorophore molecules, their images must not overlap. Therefore to reconstruct a complete image, many molecules must be localized in sequential frames, and the molecules must in some way be “switched off”.

3.6 Terms related to surface area measurement

3.6.1
mass specific surface area
absolute surface area of the sample divided by sample mass

Note 1 to entry: Mass specific surface area has units of m^2/kg.

[SOURCE: ISO 9277:2010, definition 3.11, modified]

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3.6.2
volume specific surface area
absolute surface area of the sample divided by sample volume

Note 1 to entry: Volume specific surface area has units of m^{-1}.

[SOURCE: ISO 9277:2010, definition 3.11, modified]

3.6.3
Brunauer–Emmett–Teller method
BET method
method for the determination of the total specific external and internal surface area of disperse powders and/or porous solids by measuring the amount of physically adsorbed gas utilizing the model developed by Brunauer, Emmett and Teller for interpreting gas adsorption isotherms

Note 1 to entry: Method originates from Brunauer, S., Emmett, P.H. and Teller, E.: Adsorption of gases in multimolecular layers, *J. Am. Chem. Soc.* **60** (1938) p. 309.

Note 2 to entry: The BET method is applicable only to adsorption isotherms of type II (disperse, nonporous or macroporous solids) and type IV (mesoporous solids, pore diameter between 2 nm and 50 nm). Inaccessible pores are not detected. The BET method cannot reliably be applied to solids which absorb the measuring gas.

4 Terms related to chemical analysis

The following are the definitions of terms related to chemical analysis. In the list below, note that the final “S” in the acronyms, given as “spectroscopy”, may also mean “spectrometer”, depending on the context. For the definition relating to the spectrometer, replace the word “method” by the word “instrument” where that appears.

4.1
optical spectroscopy
spectroscopy where the radiation consists of electromagnetic radiation in the visible, ultraviolet or infrared wavelengths

4.2
luminescence
emission, by atoms, molecules or ions in a material, of optical radiation which for certain wavelengths or regions of the spectrum is in excess of the radiation due to thermal emission from that material at the same temperature, as a result of these particles being excited by energy other than thermal agitation

[SOURCE: IEC 60050-845:1987, definition 04-18]

4.3
photoluminescence
luminescence (4.2) caused by absorption of optical radiation

[SOURCE: IEC 60050-845:1987, definition 04-19]

4.4
photoluminescence spectroscopy
PL spectroscopy
spectroscopy of adsorbed and re-radiated photons

4.5
fluorescence spectroscopy
spectroscopy of emitted light from a substance that has been illuminated

4.6
UV–Vis spectroscopy
spectroscopy of radiation that consists of electromagnetic radiation with wavelengths in the ultraviolet and/or visible regions

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4.7
fluorescence correlation spectroscopy
FCS
spectroscopy using a correlation analysis of the fluctuation in the *fluorescence* (3.5.12) intensity

Note 1 to entry: The analysis gives the average number of fluorescent *particles* (2.9) and average diffusion time, when the particle is passing through the measurement volume. Eventually, both the concentration and size of the particle (molecule) are determined.

4.8
Fourier transform infrared spectroscopy
FTIR
method in which a sample is subjected to excitation of molecular bonds by pulsed, broad-band infra-red radiation, and the Fourier transform mathematical method is used to obtain an absorption spectrum

[SOURCE: ISO 13943:2008, definition 4.158, modified]

4.9
Raman effect
emitted radiation, associated with molecules illuminated with monochromatic radiation, characterized by an energy loss or gain arising from rotational or vibrational excitations

[SOURCE: ISO 18115-2, definition 6.128]

4.10
Raman spectroscopy
spectroscopy in which the *Raman effect* (4.9) is used to investigate molecular energy levels

[SOURCE: ISO 18115-2, definition 6.129]

4.11
surface enhanced Raman spectroscopy
SERS
enhanced *Raman effect* (4.9) observed for certain molecules or *nano-objects* (2.2) adsorbed to particular metal surfaces whose roughness is in the *nanoscale* (2.1) when illuminated with suitable light

Note 1 to entry: Typically metals where varying degrees of enhancement is observed include gold, silver, copper, and aluminium.

Note 2 to entry: The roughness of a surface is typically in the range of a few tens of nanometres for enhancement to occur.

4.12
tip enhanced Raman spectroscopy
TERS
enhanced *Raman effect* (4.9) observed with a metal tip in close proximity to a sample surface illuminated with suitably polarized light

[SOURCE: ISO 18115-2, definition 4.43]

4.13
electron spectrometer
device, the essential part of which is used for measuring the number of electrons, or an intensity proportional to that number, as a function of the electron kinetic energy

Note 1 to entry: The term electron spectrometer may be used either as a synonym for electron energy analyser or to describe a more complex instrument based on an electron energy analyser and additional electron-optical components. Occasionally, the term is used to describe a complete working system with an energy analyser, possible electron-optical components, an electron detector, excitation sources, vacuum pumps, control electronics and a data-processing system. The meaning will normally be made clear by the context.

[SOURCE: ISO 18115-1, definitions 5.187 and 5.190, modified]

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4.14
electron energy loss spectroscopy
EELS
method in which an *electron spectrometer* (4.13) measures the energy spectrum of electrons from a nominally monoenergetic source emitted after inelastic interactions with the sample, often exhibiting peaks due to specific inelastic loss processes

Note 1 to entry: The spectrum obtained using an incident-electron beam of about the same energy as in *Auger electron spectroscopy (AES)* (4.16) or *X-ray photoelectron spectroscopy (XPS)* (4.18) peak approximates to the energy loss spectrum associated with that peak.

Note 2 to entry: The electron energy loss spectrum, measured with an incident-electron beam, is a function of the beam energy, the angle of incidence of the beam, the angle of emission and the electronic properties of the sample.

[SOURCE: ISO 18115-1, definition 5.197, modified]

4.15
Auger electron
electron emitted from atoms in the relaxation, by electron emission, of an atom with a vacancy in an inner electron shell

Note 1 to entry: The emitted electrons have characteristic energies.

[SOURCE: ISO 18115-1, definitions 5.37, modified]

4.16
Auger electron spectroscopy
AES
method in which an *electron spectrometer* (4.13) is used to measure the energy distribution of *Auger electrons* (4.15) emitted from a surface

Note 1 to entry: An electron beam in the energy range 2 keV to 30 keV is often used for excitation of the Auger electrons. Auger electrons can also be excited with X-rays, ions and other sources but the term Auger electron spectroscopy, without additional qualifiers, is usually reserved for electron-beam-induced excitation. Where an X-ray source is used, the Auger electron energies are referenced to the Fermi level but, where an electron beam is used, the reference may either be the Fermi level or the vacuum level. Spectra conventionally may be presented in the direct or differential forms.

[SOURCE: ISO 18115-1, definition 4.1]

4.17
ultraviolet photoelectron spectroscopy
UPS
method in which an *electron spectrometer* (4.13) is used to measure the energy distribution of photoelectrons emitted from a surface irradiated by ultraviolet photons

Note 1 to entry: Ultraviolet sources in common use include various types of discharges that can generate the resonance lines of various gases (e.g. the He I and He II emission lines at energies of 21,2 eV and 40,8 eV, respectively). For variable energies, synchrotron radiation is used.

[SOURCE: ISO 18115-1, definition 4.22]

4.18
X-ray photoelectron spectroscopy
XPS
method in which an *electron spectrometer* (4.13) is used to measure the energy distribution of photoelectrons and *Auger electrons* (4.15) emitted from a surface irradiated by X-ray photons

Note 1 to entry: X-ray sources in common use are unmonochromated Al Ka and Mg Ka X-rays at 1 486,6 eV and 1 253,6 eV, respectively. Modern instruments also use monochromated Al Ka X-rays. Some instruments make use of various X-ray sources with other anodes or of synchrotron radiation.

[SOURCE: ISO 18115-1, definition 4.23]

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4.19
X-ray absorption spectroscopy
XAS
method in which the absorption of X-rays passing through matter is measured as a function of X-ray energy

Note 1 to entry: The method is used to determine local geometric and/or electronic structure of matter.

Note 2 to entry: X-ray absorption fine structure spectroscopy (XAFS), X-ray absorption near-edge spectroscopy (XANES), near-edge extended X-ray absorption fine structure spectroscopy (NEXAFS) are all types of X-ray absorption spectroscopy.

4.20
X-ray fluorescence
XRF
secondary radiation occurring when a high intensity incident X-ray beam impinges upon a material placed in the path of the incident beam

Note 1 to entry: The secondary emission has wavelengths and energies characteristic of that material.

[SOURCE: ISO 3497:2000]

4.21
energy-dispersive X-ray spectroscopy
EDS or EDX
X-ray spectrometry in which the energy of individual photons are measured by a parallel detector and used to build up a histogram representing the distribution of X-rays with energy

[SOURCE: ISO 22309:2011, definition 3.11, modified]

4.22
inductively coupled plasma mass spectrometry
ICP-MS
method in which a high-temperature discharge generated in flowing argon by an alternating magnetic field induced by a radio-frequency (RF) load coil that surrounds the tube carrying the gas is detected using a mass spectrometer

[SOURCE: ISO 15202-3:2004, definition 3.3.7, modified]

4.23
secondary-ion mass spectrometry
SIMS
method in which a mass spectrometer is used to measure the mass-to-charge quotient and abundance of secondary ions emitted from a sample as a result of bombardment by energetic ions

Note 1 to entry: SIMS is, by convention, generally classified as dynamic, in which the material surface layers are continually removed as they are being measured, and static, in which the ion areic dose during measurement is restricted to less than 10^{16} ions/m^2 in order to retain the surface in an essentially undamaged state.

[SOURCE: ISO 18115-1, definition 4.17]

4.24
atom-probe tomography
method for identifying single atoms or molecules removed from a *nanofibre* (2.6) by pulsed field evaporation and detection by time of flight mass spectrometry

Note 1 to entry: A position-sensitive detector is used to deduce the lateral location of atoms.

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4.25
evolved-gas analysis
EGA
method in which the nature and/or amount of volatile product(s) released by a substance is (are) measured as a function of temperature while the substance is subjected to a controlled temperature programme

[SOURCE: ISO 472:2013, definition 2.345, modified]

4.26
nuclear magnetic resonance spectroscopy
NMR spectroscopy
method where the resonance magnetic properties of atomic nuclei are used to determine physical and chemical properties of atoms and molecules

4.27
electron paramagnetic resonance
EPR
electron spin resonance (ESR)
method for studying chemical species that have one or more unpaired electrons through resonant excitation of electron spin

Note 1 to entry: Similar to NMR but measuring electron spin.

4.28
Mössbauer spectroscopy
recoil-free nuclear emission and resonant absorption of gamma radiation

[SOURCE: ISO 921:1997, definition 764]

4.29
dual polarization interferometry
DPI
method in which the evanescent wave of a laser beam is used to probe molecular scale layers adsorbed to the surface of a waveguide

Note 1 to entry: The polarization can be switched rapidly, allowing real-time measurements of chemical reactions taking place on a chip surface in a flow-through system.

Note 2 to entry: Typically used to measure the conformational change in proteins or other biomolecules as they interact with their environment.

5 Terms related to measurement of other properties

5.1 Terms related to mass measurement

5.1.1
quartz crystal microbalance
QCM
method in which the change in frequency of a quartz crystal resonator is measured to determine a change in mass

Note 1 to entry: Can be used under vacuum, in gas phase or in liquid environments.

5.1.2
thermogravimetry
TG
method in which the change in mass of a sample is measured as a function of temperature while the sample is subjected to a controlled temperature programme

[SOURCE: ISO 472:2013, definition 2.1173, modified]

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5.1.3
differential scanning calorimetry
DSC
method in which the difference in energy inputs into a substance and a reference material is measured as a function of temperature while the substance and reference material are subjected to a controlled temperature programme

[SOURCE: ISO 472:2013, definition 2.278, modified]

5.2 Terms related to crystallinity measurement

5.2.1
X-ray diffraction
method to obtain crystallographic information about a sample by observing the diffraction pattern due to an X-ray beam hitting a sample

Note 1 to entry: The method can be used to estimate the size of coherent scattering regions.

5.2.2
electron backscatter diffraction
EBSD
diffraction process that arises between the backscattered electrons and the atomic planes of a highly tilted crystalline specimen when illuminated by a stationary incident electron beam

[SOURCE: ISO 24173:2009, definition 3.7]

5.3 Terms related to charge measurement in suspensions

5.3.1
electrophoretic velocity
particle (2.9) velocity during electrophoresis

Note 1 to entry: Electrophoretic velocity is expressed in metres per second.

[SOURCE: ISO 13099-1:2012, definition 2.2.6]

5.3.2
electrophoretic mobility
electrophoretic velocity per electric field strength

Note 1 to entry: Electrophoretic mobility is positive if the *particles* (2.9) move toward lower potential (negative electrode) and negative in the opposite case.

Note 2 to entry: Electrophoretic mobility is expressed in metres squared per volt second.

[SOURCE: ISO 13099-1:2012, definition 2.2.5]

5.3.3
slipping plane
shear plane
abstract plane in the vicinity of the liquid/solid interface where liquid starts to slide relative to the surface under influence of a shear stress

[SOURCE: ISO 13099-1:2012, definition 2.1.11]

5.3.4
electrokinetic potential
zeta potential
difference in electric potential between that at the slipping plane and that of the bulk liquid

Note 1 to entry: Electrokinetic potential is expressed in volts.

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[SOURCE: ISO 13099-1:2012, definition 2.1.8]

5.3.5
electric surface charge density
charges on an interface per area due to specific adsorption of ions from the liquid bulk, or due to dissociation of the surface groups

Note 1 to entry: Electric surface charge density is expressed in coulombs per square metre.

[SOURCE: ISO 13099-1:2012, definition 2.1.6]

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Annex A
(informative)

Index

aerosol	2.12
agglomerate	2.10
aggregate	2.11
aspect ratio	3.1.4
atom-probe tomography	4.24
atomic force microscopy, AFM	3.5.2
Auger electron	4.15
Auger electron spectroscopy, AES	4.16
Brunauer-Emmett-Teller method, BET method	3.6.3
centrifugal liquid sedimentation, CLS	3.4.2
condensation particle counter, CPC	3.3.1
confocal optical microscopy	3.5.10
Coulter counter	3.4.4
differential centrifugal sedimentation, DCS	3.4.2
differential electrical mobility classifier, DEMC	3.3.2
differential mobility analysing system, DMAS	3.3.3
differential scanning calorimetry, DSC	5.1.3
dual polarization interferometry, DPI	4.29
dynamic light scattering, DLS	3.2.7
electric surface charge density	5.3.5

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electrical zone sensing 3.4.4

electrokinetic potential 5.3.4

electron backscatter diffraction,
EBSD 5.2.2

electron energy loss spectroscopy,
EELS 4.14

electron paramagnetic resonance, EPR 4.27

electron spin resonance, ESR 4.27

electron spectrometer 4.13

electrophoretic mobility 5.3.2

electrophoretic velocity 5.3.1

energy-dispersive X-ray spectroscopy,
EDS or EDX 4.21

equivalent diameter 3.1.5

evolved-gas analysis,
EGA 4.25

Faraday-cup aerosol electrometer,
FCAE 3.3.4

field flow fractionation,
FFF 3.4.1

fluorescence 3.5.12

fluorescence correlation spectroscopy 4.7

fluorescence microscopy 3.5.13

fluorescence spectroscopy 4.5

Fourier transform infrared spectroscopy,
FTIR 4.8

hydrodynamic diameter 3.2.6

inductively coupled plasma mass spectrometry,
ICP-MS 4.22

light scattering 3.2.5

localization microscopy 3.5.16

low energy electron microscopy,
LEEM 3.5.8

luminescence 4.2

mass specific surface area 3.6.1

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Mössbauer spectroscopy 4.28

nanofibre 2.6

nano-object 2.2

nanoparticle 2.3

nanoparticle tracking analysis,
NTA 3.2.8

nanoplate 2.4

nanorod 2.5

nanoscale 2.1

nanotube 2.7

near-field scanning optical microscopy,
NSOM 3.5.4

neutron diffraction 3.2.3

nuclear magnetic resonance spectroscopy,
NMR spectroscopy 4.26

optical spectroscopy 4.1

particle 2.9

particle shape 3.1.3

particle size 3.1.1

particle size distribution 3.1.2

particle tracking analysis,
PTA 3.2.8

photoluminescence 4.3

photoluminescence spectroscopy,
PL spectroscopy 4.4

photon correlation spectroscopy,
PCS 3.2.7

quantum dot 2.8

quartz crystal microbalance,
QCM 5.1.1

quasi-elastic light scattering,
QELS 3.2.7

radius of gyration 3.2.1

Raman effect 4.9

Raman spectroscopy 4.10

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scanning electron microscopy,
SEM 3.5.5

scanning ion microscopy, 3.5.9

scanning near-field optical microscopy,
SNOM 3.5.4

scanning probe microscopy,
SPM 3.5.1

scanning transmission electron microscopy,
STEM 3.5.7

scanning tunnelling microscopy,
STM 3.5.3

secondary-ion mass spectrometry,
SIMS 4.23

shear plane 5.3.3

size-exclusion chromatography,
SEC 3.4.3

slipping plane 5.3.3

small angle neutron scattering,
SANS 3.2.2

small angle X-ray scattering,
SAXS 3.2.4

super-resolution microscopy 3.5.15

surface enhanced ellipsometric contrast microscopy,
SEEC microscopy 3.5.11

surface enhanced Raman spectroscopy,
SERS 4.11

suspension 2.13

thermogravimetry,
TG 5.1.2

tip enhanced Raman spectroscopy,
TERS 4.12

total internal reflection fluorescence microscopy,
TIRF microscopy 3.5.14

transmission electron microscopy,
TEM 3.5.6

ultraviolet photoelectron spectroscopy,
UPS 4.17

UV-Vis spectroscopy 4.6

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volume specific surface area 3.6.2

X-ray absorption spectroscopy,
XAS 4.19

X-ray diffraction 5.2.1

X-ray fluorescence,
XRF 4.20

X-ray photoelectron spectroscopy,
XPS 4.18

zeta potential 5.3.4

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