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Contents

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 9 and a back cover.

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Foreword

Publishing information

This Publicly Available Specification (PAS) has been commissioned by the UK Department for Innovation, Universities and Skills (DIUS) and developed through the British Standards Institution (BSI). It came into effect on 31 December 2007.

Acknowledgement is given to the following organizations that were involved in the development of this terminology:

- Cambridge University;
- Cytec;
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- NanoCentral;
- National Physical Laboratory;
- ONE NorthEast.

In addition, acknowledgement is given to the contributions of those that commented, including BSI Technical Committee NTI/1, *Nanotechnologies*, the working groups of ISO Technical Committee ISO/TC 229, *Nanotechnologies*, and other organizations and experts.

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The PAS process enables a specification to be rapidly developed in order to fulfil an immediate need in industry. A PAS may be considered for further development as a British Standard, or constitute part of the UK input into the development of a European or International Standard.

Relationship with other publications

This PAS is issued as part of a suite of nanotechnology terminology PASs:

- PAS 71, *Vocabulary – Nanoparticles*;
- PAS 131, *Terminology for medical, health and personal care applications of nanotechnologies*;
- PAS 132, *Terminology for the bio-nano interface*;
- PAS 133, *Terminology for nanoscale measurement and instrumentation*;
- PAS 134, *Terminology for carbon nanostructures*;
- PAS 135, *Terminology for nanofabrication*;
- PAS 136, *Terminology for nanomaterials*.

PAS 131 to PAS 136 include terms the definitions for which differ to those given in PAS 71:2005, which was published a few years earlier. These differences are the result of further reflection and debate and reflect consensus within the PAS steering groups. Until PAS 71:2005 can be revised to incorporate these changes, it is intended that the terms in PAS 131 to PAS 136 take precedence over PAS 71:2005.

This suite of PASs acknowledges the standards development work being conducted by BSI Technical Committee NTI/1, *Nanotechnologies*, ISO TC/229, *Nanotechnologies*, IEC/TC 113, *Nanotechnology standardization for electrical and electronic products and systems*, and CEN/TC 352, *Nanotechnologies*. Attempts have been made to align the definitions in these PASs with the definitions being developed by these committees, particularly the draft ISO/TS 27687, *Terminology and definitions for nanoparticles*. However, as the work of these committees is at a development stage, complete alignment has not been possible in every instance.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Introduction

Many authorities predict that applications of nanotechnologies will ultimately pervade virtually every aspect of life and will enable dramatic advances to be realized in most areas of communication, health, manufacturing, materials and knowledge-based technologies. Even if this is only partially true, there is an obvious need to provide industry and research with suitable tools to assist the development, application and communication of the technologies. One essential tool in this armoury will be the harmonization of the terminology and definitions used in order to promote their common understanding and consistent usage.

This terminology includes terms that are either specific to the sector covered by the title or are used with a specific meaning in the field of nanotechnology. It is one of a series of terminology PASs covering many different aspects of nanotechnologies.

This terminology attempts not to include terms that are used in a manner consistent with a definition given in the *Oxford English Dictionary* [1], and terms that already have well established meanings and to which the addition of the prefix "nano" changes only the scale to which they apply but does not otherwise change their meaning.

The multidisciplinary nature of nanotechnologies can lead to confusion as to the precise meaning of some terms because of differences in usage between disciplines. Users are advised that, in order to support the standardization of terminology, this PAS provides single definitions wherever possible.

1 Scope

This Publicly Available Specification (PAS) lists terms and definitions used in or associated with the naming, describing and manufacture of nanomaterials.

It is applicable to, though not limited to, elemental, compound, organic, inorganic, metallic, ceramic, polymeric and oxide materials with nanostructural features including nano-crystallinity, nano-porosity, nano-reinforcement and deliberately produced nano-topography.

This PAS is intended for use by technologists, regulators, non-governmental organizations (NGOs), consumer organizations, members of the public and others with an interest in the application or use of nanomaterials.

2 General

2.1 agglomerate
collection of loosely bound particles or **aggregates** 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 The forces holding an agglomerate together are weak forces, for example van der Waals forces, as well as simple physical entanglement.

[ISO/TS 27687[1)]]

2.2 aggregate
particle 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 The forces holding an aggregate together are strong forces, for example covalent bonds, or those resulting from sintering or complex physical entanglement.

[ISO/TS 27687[1)]]

2.3 mesoporous
possessing pores with at least one dimension between 2 nm to 50 nm

*NOTE The term **nanoporous** is preferred to mesoporous.*

2.4 nanomaterial
material having one or more external dimensions in the **nanoscale** or which is **nanostructured**

*NOTE **Nanomaterials** can exhibit properties that differ from those of the same material without **nanoscale** features.*

2.5 nano-object
discrete piece of material with one or more external dimensions in the **nanoscale**

*NOTE This is a generic term for all **nanoscale** objects.*

[ISO/TS 27687[1)]]

2.6 nanoparticle
nano-object with all three external dimensions in the **nanoscale**

*NOTE If the lengths of the longest and the shortest axes of the **nano-object** differ significantly (typically by more than three times) the terms **nanorod** or **nanoplate** are intended to be used instead of the term nanoparticle.*

[ISO/TS 27687[1)]]

2.7 nanoporous
possessing pores with at least one dimension in the **nanoscale**

*NOTE The term nanoporous is preferred to **mesoporous**.*

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1) In preparation.

2.8 nanoscale
size range from approximately 1 nm to 100 nm

NOTE 1 Properties that are not extrapolations from larger size will typically, but not exclusively, be exhibited in this size range.

*NOTE 2 The lower limit in this definition (approximately 1 nm) has no physical significance but is introduced to avoid single and small groups of atoms from being designated as **nano-objects** or elements of **nanostructures**, which might be implied by the absence of a lower limit.*

[ISO/TS 27687[2)]]

2.9 nanostructure
nanoscale structure

2.10 nanostructured
possessing a structure comprising contiguous elements with one or more dimension in the **nanoscale** but excluding any primary atomic or molecular structure

NOTE 1 An example of a primary atomic or molecular structure is the arrangement of atoms in a crystalline solid.

NOTE 2 The use of the term contiguous implies that a sphere of approximately 100 nm diameter, inscribed in a nanostructured material, will intersect more than one element of the structure.

2.11 primary structure
first level of ordered structuring of matter above disorder

NOTE For example, a sequence of mer units in a polymer or amino acids in a peptide molecule.

2.12 secondary structure
second level of ordered structuring of matter above disorder

NOTE For example, a formation of inter-polymer bonds such as hydrogen bonding to give rise to beta sheets and barrel regions.

2.13 supramolecule
ordered array of molecules, held together through non covalent interactions, which exhibits at least a **primary structure**

2.14 tertiary structure
third level of ordered structuring of matter above disorder

NOTE 1 For example, the surface topography of a protein macromolecule.

NOTE 2 Higher levels of ordering are possible.

2) In preparation.

3 Molecular entities

3.1 cage compound
polycyclic compound having the shape of a cage

[IUPAC *Compendium of Chemical Terminology* 1994, 66, 1092 [2]]

3.2 fullerene
closed-cage structure having more than 20 carbon atoms consisting entirely of three-coordinate carbon atoms

NOTE A fullerene with 60 carbon atoms (C_{60}) is sometimes called buckminsterfullerene.

[*J. Chem. Inf. Comp. Sci.* 35, 969-978 [3]]

3.3 graphene
single sheet of trigonally bonded (sp^2) carbon atoms in a hexagonal structure

4 Structural entities

4.1 carbon nanotube
nanotube consisting of carbon

*NOTE This term is commonly used to refer to a seamless tube constructed from **graphene** that can be either a single-wall carbon nanotube (SWCNT), comprising a single layer of carbon atoms, or a multi-wall carbon nanotube (MWCNT), comprising multiple concentric tubes.*

4.2 micelle
aggregation of surfactant molecules dispersed in a liquid

NOTE 1 The surfactant molecules are often sequestered into hydrophilic and hydrophobic regions.

NOTE 2 Micelles are commonly spherical but can also be branched, rods or worm-like.

4.3 nanocluster
non covalently or covalently bound group of atoms or molecules whose largest overall dimension is typically in the **nanoscale**

4.4 nanofibre
flexible **nanorod**

[ISO/TS 27687[3)]]

4.5 nanoplate
nano-object with one external dimension in the **nanoscale** and the two other external dimensions significantly larger

NOTE 1 The smallest external dimension is the thickness of the nanoplate.

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

*NOTE 3 The larger external dimensions are not necessarily at the **nanoscale**.*

[ISO/TS 27687[3)]]

[3)] In preparation.

4.6 nanopowder
mass of dry **nanoparticles**

4.7 nanorod
nano-object with two similar external dimensions in the **nanoscale** and the third dimension significantly larger than the other two external dimensions

*NOTE 1 The largest external dimension is the length of the nanorod and is not necessarily in the **nanoscale**.*

NOTE 2 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 A nanorod can take any cross-sectional shape consistent with the dimensional limits of the definition.

[ISO/TS 27687[4)]]

4.8 nanotube
hollow **nanorod**

[ISO/TS 27687[4)]]

4.9 self assembled monolayer
planar two dimensional supramolecular array formed at an interface

NOTE An example of a self assembled monolayer is a Langmuir-Blodgett film.

5 Synthesized materials

5.1 aerogel
nanoporous low density (less than 5 $mg \cdot cm^{-3}$) fractal solid

5.2 dendrimer
repeatedly branched **macromolecule**

NOTE Dendrimers can be configured as a sphere, partial sphere or wedge structure (i.e. dendritic wedge).

5.3 dendron
dendrimer containing a single chemically addressable group

NOTE The single chemically addressable group is known as the focal point.

5.4 macromolecule
molecule with high relative molecular mass comprising multiple repetitive units derived from molecules of lower relative molecular mass

[derived from IUPAC *Compendium of Chemical Terminology*, 1996, 68, 2289 [2]]

5.5 nanocomposite
multiphase structure in which at least one of the phases has at least one dimension in the **nanoscale**

[derived from *Pure and Applied Chemistry*, pp 1985–2007 [4]]

4) In preparation.

5.6 sol-gel
colloidal system in which a porous network of interconnected particles spans the volume of a liquid medium

NOTE Particles in a sol-gel are often ***nanoparticles****.*

5.7 zeolite
nanoporous crystalline solid with a well defined pore structure

6 Production of raw material

6.1 bottom up
progressing from small or subordinate units to a larger and functionally richer unit

[derived from *The American Heritage Dictionary of the English Language* [5]]

6.2 chemical vapour synthesis
production method where vapour, introduced to a reaction chamber by, for example, pyrolysis, reduction, oxidation or nitridation, condenses to form particles

NOTE 1 Also referred to as chemical vapour growth.

NOTE 2 One application is the synthesis of ***carbon nanotubes****.*

[derived from PAS 71:2005, definition **6.5**]

6.3 electrospinning
technique used to produce **nanofibres** from a reservoir of reactive precursor species expelled through a nozzle, the tip of which is held at high voltage, the fibres being collected on a grounded plate

6.4 flame pyrolysis
synthesis method where flame heat is used to vaporize feedstock material and initiate chemical reaction to produce particles

NOTE Particles produced by flame pyrolysis are often ***nanoparticles****.*

[derived from *Nanoparticles: An occupational hygiene review* [6]]

6.5 laser pyrolysis
gas phase synthesis method where a flowing reactive gas is heated rapidly with a laser

[PAS 71:2005, definition **6.19**]

6.6 nanolithography
process of defining an arbitrary pattern with minimum feature sizes of less than 100 nm

6.7 nanoprinting
preparation of **nanomaterials** or **nanostructures** using techniques allied to printing

6.8 plasma processing
use of plasma to effect changes in materials

6.9 plasma synthesis
use of high energy plasma to vaporize materials, and promote reactions, for the production of other material

NOTE Materials produced by plasma synthesis are often ***nanomaterials****.*

6.10 self assembly
assembling of components to create a new level of organization without external input

6.11 sol-gel processing
production process involving the conversion of a sol to a gel, which is then desiccated to produce particles or a film

[derived from PAS 71:2005, definition **6.23**]

6.12 templating
use of a preformed entity to impart structural and positional ordering

6.13 top down
process that progresses from larger units to smaller units

[derived from *The American Heritage Dictionary of the English Language* [5]]

7 Production of constructed material

7.1 atomic layer deposition (ALD)
deposition process based on sequential pulsing of chemical precursor vapours, with each pulse forming one atomic layer

7.2 cluster beam deposition
process of thin film formation from a beam of atomic or molecular clusters

NOTE 1 Typically the beam used is supersonic.

NOTE 2 This form of deposition is often used to produce structures with a high degree of porosity for gas sensing applications.

7.3 evaporation induced self assembly
use of a dilute precursor solution to form surface patterning or structures on a substrate following evaporation of the solvent

7.4 high shear rate processing
mechanical dispersion, deagglomeration, disaggregation or liquid particle generation process using shear mixing forces to produce **nanomaterials**

7.5 high strain rate processing
mechanical processing using strain to produce **nanomaterials**

7.6 mechanical alloying
process consisting of the repeated bonding, fracturing and rebonding of elemental or master alloy powders by highly energetic collisions in a mill under an inert atmosphere or vacuum

NOTE This process can be used to produce alloyed ***nanomaterials****.*

[derived from PAS 71:2005, definition **6.20**]

7.7 molecular beam epitaxy (MBE)
technique of growing single crystals in which beams of atoms or molecules are made to strike a single-crystalline substrate in a vacuum, giving rise to crystals whose crystallographic orientation is related to that of the substrate

NOTE 1 The beam is defined by allowing the vapour to escape from the evaporation zone to a high vacuum zone through a small orifice.

NOTE 2 ***Nanostructures*** *can be grown in this method by exploiting strain, e.g. InAs dots on GaAs substrate.*

[*McGraw-Hill Dictionary of Scientific and Technical Terms* [7]]

Bibliography

Standards publications

For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/TS 27687, *Terminology and definitions for nanoparticles*[5)]

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Other publications

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[7] *McGraw-Hill Dictionary of Scientific and Technical Terms*. 6th edition. New York: McGraw-Hill, 2002.

Further reading

PAS 130, *Guidance on the labelling of manufactured nanoparticles and products containing manufactured nanoparticles*

PD 6699-1, *Nanotechnologies – Part 1: Good practice guide for specifying manufactured nanomaterials*

PD 6699-2, *Nanotechnologies – Part 2: Guide to safe handling and disposal of manufactured nanomaterials*

5) In preparation.

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