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BS PAS 132 (2007) (English): Terminology for the bio-nano interface

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PAS 132:2007

PUBLICLY AVAILABLE SPECIFICATION

Terminology for the bio-nano interface

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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. It came into effect on 31 December 2007.

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- Cranfield University;
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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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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 in June 2005. 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 PAS 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.

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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.

As with all the PAS documents in the series, the remit for its preparation was to "document and, to a lesser degree, comment on the current use of basic terms and definitions by manufacturers, suppliers, academia, regulators and governments, and to give recommendations for usage". In the case of such a cross-disciplinary field as bionanotechnology, there is particularly wide variation of current usage; and on the other hand, since the technology is rather new, an easily identifiable body of manufacturers and suppliers, let alone of regulators, from whom one can garner usage scarcely exists; indeed, a majority of the commercial firms involved are recent academic spin-offs.

1 Scope

This Publicly Available Specification (PAS) lists terms and definitions used in or associated with the naming or describing of applications of nanotechnologies and nanomaterials to or at the bio-nano interface.

It is applicable to, though is not limited to, the use of nanotechnologies in diagnostic devices, including bio-nano diagnostic systems, quantum dots and other nano-bio-markers for the identification and/or tracing of biological entities, and in vitro and in vivo interactions of nanomaterials with biological systems.

It is intended for use by technologists, manufacturers, regulators, non-government organizations (NGOs), consumer organizations, members of the public and others with an interest in the application or use of nanotechnologies in the subject area.

2 Terms and definitions

2.1 analyte
entity under analysis, such as a molecule in solution (could equally apply to gas-borne molecules)

2.2 aptamer
polymer of limited length (**oligomer**), e.g. single-stranded RNA or DNA, which can fold into a wide variety of 3-dimensional shapes, that binds highly specifically to a wide range of ligands, molecules and **biomaterials**

2.3 bio
related to, or concerning life

2.4 bioactive
engineered to evoke a positive response from the host body

2.5 biocompatible
tolerant of life, or of biomolecular function

2.6 biofilm
naturally formed composite **biomaterial**

*NOTE Bacterial **biofilm**s are formed by bacteria that generate and secrete the matrix molecules cementing them together.*

2.7 biofunctionalization
1. modification of a non-biological material, device or system in order to make it **biocompatible** or **biointeractive**

2. modification with biologically-derived material

2.8 bioinert
not evoking any significant response from the host organism or biological system

2.9 biointeractive
1. enabled for the exchange of information between a biological system and a non-biological one

2. capable of sending and/or receiving information from a living organism

NOTE This encompasses physico-chemical interplay between surface and matrix (which is fundamentally encoded information).

2.10 biomaterial
1. any substance, synthetic or natural, that can be used as a system or part of a system that treats, augments, or replaces any tissue, organ, or function of the body

[ASTM International, Designation: F2312-04. *Standard Terminology Relating to Tissue Engineered Medical Products* [2]]

2. any material produced using a biological system, or any material produced in vitro that could be made by a biological system

2.11 biomimicry
artificial process or material designed to imitate a natural one

*NOTE Biomimetic is the adjective of **biomimicry**.*

2.12 biomineralization
1. synthesis of inorganic crystalline or amorphous mineral-like materials by living organisms

[*Glossary of terms used in bioinorganic chemistry.* IUPAC Recommendations 1997 [3]]

2. process of incorporating inorganic atoms or aggregates into biological material to create a composite structure

2.13 bioNEMS
nanoelectromechanical system incorporating biological functionality

2.14 biorecognition
synonym for **specific binding**

2.15 biotin (vitamin b_7) / (strept)avidin
streptavidin is a tetrameric protein, isolated from *Streptomyces avidinii*, that binds the peptide **biotin** with a dissociation constant of 10^{-14} M^{-1}

NOTE 1 This effectively means the binding is so tight that the two molecules rarely separate.

*NOTE 2 The **biotin-streptavidin** complex is often used as a model.*

2.16 Brownian ratchet
device for extracting work from an external energy source, in apparent contradiction of the second law of thermodynamics

2.17 capture layer
thin film with the function of capturing and concentrating an **analyte** (for example, placed on the **transducer** element of a biosensor)

2.18 cell spreading
process of shape transformation (e.g. sphere to segment), undergone by a cell initially suspended in a culture medium when it settles on and adheres to a solid surface

2.19 cofactor
molecule required by an enzyme to achieve normal function

2.20 confocal microscopy
technique used to increase image contrast and/or to reconstruct 3-dimensional images by using a spatial pinhole to eliminate out-of-focus light or flare in specimens that are thicker than the focal plane

2.21 datività
electron donor potential

2.22 directed growth
encouragement of cell growth at particular sites and cell differentiation, e.g. through the use of growth factors, chemotaxis, electrical or mechanical factors (cf. mechanotransduction), or topographic features in the surrounding neighbourhood

2.23 engineered surface
surface designed and fabricated for a particular application

2.24 evanescent wave
monotonically decaying wave formed when an electromagnetic wave is reflected off an interface between two different transparent dielectrics at an angle greater than the critical angle so that total internal reflection occurs; typically coupled to an electeromagnetic mode (standing wave) inside a waveguide

NOTE Synonymous with evanescence field.

2.25 extracellular matrix
complex mass of large secreted glycoproteins in which cells are embedded and supported

2.26 fluorescence correlation spectroscopy (FCS)
method to determine the diffusion coefficients of molecules by measuring the decay kinetics of fluorescence excited by polarized light

NOTE Also known as fluorescence anisotropy decay spectroscopy.

2.27 fluorescence resonance energy transfer (FRET)
energy transfer between two fluorescent molecules

NOTE 1 Also known as Förster energy transfer.

NOTE 2 A fluorescent donor is excited at its fluorescence excitation wavelength. By a short-range dipole-dipole coupling mechanism, the energy of this excited state is then nonradiatively transferred to a second molecule, the acceptor, whereupon the donor returns to the electronic ground state.

2.28 focal adhesion
transmembrane junction between the **extracellular matrix**, or any **substrate** on which living cells are growing, and the cytoskeleton

2.29 focal contact
region of closest approach (less than 10 nm) of plasma membrane to another cell or **substratum**

*NOTE **Focal contacts** are often characterized in terms of the proteins involved.*

2.30 his-tag
short amino acid sequence including histidines, often fused to one end of a protein, and which will bind transition metal cations, facilitating protein purification

2.31 hydrophilic
interfacial free energy $\Delta G_{1w1} > 0$, where 1 = **substrate** and w = water; shows a preference for an aqueous environment

*NOTE It can be derived from contact angle measurements made with different liquids. A **hydrophilic substrate** would give an (advancing) contact angle with water of 0 (i.e. the **substrate** is fully wetted).*

[*The hydrophilicity and hydrophobicity of clay minerals* [4]]

2.32 hydrophobic
the interfacial free energy $\Delta G_{1w1} < 0$, where 1 = **substrate** and w = water; shows a preference for a non-polar (apolar) environment

*NOTE It can be derived from contact angle measurements made with different liquids. A **hydrophobic substrate** would give a contact angle with water > 0. In practice, however, substances with advancing contact angles up to 10 or more degrees might still be considered to be **hydrophilic**.*

[*The hydrophilicity and hydrophobicity of clay minerals* [4]]

2.33 *kT*
thermal energy of a system

NOTE The phrase derives from Boltzmann's equation, where k is Boltzmann's constant and T is temperature (in Kelvin). Often k is written as "k_B".

2.34 lab-on-a-chip
micro- or **nanoscale** device in which small numbers of molecules can be subjected to different localized chemistries

NOTE "Chip" refers to integrated sensors, sample handling and electronics fitting onto a silicon chip-sized device.

2.35 laminar flow
fluid flow occurring in parallel layers without mixing between the layers, experimentally found for **Reynolds numbers** < 2000

2.36 laser tweezers
intense focused light beam used to trap and manipulate nanoscopic objects

NOTE Also known as an optical trap.

2.37 lotus effect
biomimicry of the superhydrophobicity observed with leaves from the lotus plant (N. nucifera) , caused by its surface being roughened in a highly specific manner

[derived from *Purity of the sacred lotus, or escape from contamination in biological surfaces* [5]]

2.38 magnetic tweezers
device for measuring the displacement of a magnetic particle tethered to a single biomolecule or cell, with the particle being manipulated in space by an external magnetic field

*NOTE With DNA as the **biomaterial** the magnetic bead can be tethered through the DNA to a surface and acts as a pendulum. Vertical motion of the bead (e.g. due to a motor pulling the DNA) can be visualized through changes in the diffraction rings around the bead. This allows determination of the height of the bead ± 8 nm.*

2.39 microfluidics
fluid-transporting channels in the range of 100 nm – 10 micrometre width

*NOTE Typically used to enable **laminar flow** of soluble material.*

2.40 molecular machine
chemically or biologically produced molecule, or collection of molecules that can perform useful work

2.41 molecular motor
molecular machine that produces linear or rotary motion

*NOTE Generally speaking, a motor may be defined as a device that consumes energy in one form and converts it into motion or mechanical work; for example, many protein-based **molecular motors** harness the chemical free energy released by the hydrolysis of ATP in order to perform mechanical work. Usually they can also carry out the reverse operation, i.e. generate chemical free energy from mechanical work (**molecular generator**).*

2.42 molecular generator
molecular machine that produces chemical free energy from linear or rotary motion

2.43 molecular recognition element
component designed to detect (usually) a single type of molecule, typically used in biosensors (cf. **capture layer**)

2.44 motility
ability of a cell to migrate (move)

2.45 nano
prefix used to denote the presence of significant features existing or processes operating within the nanoscale

2.46 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.*

2.47 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[1)]]

2.48 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.*

2.49 non-specific binding
binding of one molecule to another, or of a molecule or living cell to a surface, that does not depend on unique features of the arrangement of atoms of one or both of the binding partners

1) In preparation.

2.50 oligomer (oligo)
short polymer, made by deliberate successive single stepwise polymerization

2.51 optical waveguide lightmode spectroscopy (OWLS)
measurement of the spectrum of guided modes in an optical waveguide, typically using a diffraction grating or interferometry

2.52 phage display
production of recombinant polypeptide on the outer surface of a bacteriophage

2.53 photonic structure
structure, typically interacting via scattering or interference, with light

NOTE The wings and/or wing cases of many brilliantly coloured butterflies, moths and beetles are natural ***photonic structures****.*

2.54 plaque
biofilm

NOTE 1 Dental ***plaque*** *is a bacterial* ***biofilm*** *formed on teeth and gums, arterial* ***plaque*** *is a composite of various blood proteins and cholesterol, incorporating* Ca^{2+}.

NOTE 2 In virology, ***plaque*** *refers to an area of restricted growth of a virus on a host monolayer.*

2.55 quantum dot
discrete **nanoscale** semiconductor or metal structure that exhibits size-dependent electronic and optical properties due to quantum confinement

[derived from *Occupational Ultrafine Aerosol Exposure Characterization and Assessment* [6]]

2.56 recettività
electron acceptor potential

2.57 Reynolds number
dimensionless ratio of inertial forces to frictional forces in a fluid

NOTE ***Reynolds number*** *= (2 × radius × density × velocity) / (viscosity). For values > 3 000 the flow is turbulent, for < 2 000 it is laminar and for 2 000–3 000 the flow can switch between the two states.*

2.58 RGD
sequence of three amino acids (arginine, glycine, aspartic acid) found in the cell-binding domain of fibronectin, an extracellular matrix protein

NOTE This sequence is often used to promote cell binding to ***tissue scaffolds****.*

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

2.60 sensorization
embedding large numbers of sensors in a structure

2.61 slipping plane
when solid and fluid phases are in relative motion, the plane that divides the fluid entrained with the solid from the rest of the fluid

2.62 smart
designed to respond to external stimuli

2.63 solvophilic
interfacial free energy $\Delta G_{1f1} > 0$, where 1 = **substrate** and f = fluid (cf. **hydrophilic**)

2.64 solvophobic
interfacial free energy $\Delta G_{1f1} < 0$, where 1 = **substrate** and f = fluid (cf. **hydrophobic**)

2.65 specific binding
high-affinity binding of one molecule to another, or of a molecule or living cell to a surface, that depends on unique features of the arrangement of atoms of one or both of the binding partners

2.66 substrate
1. surface on which material is deposited (also known as **substratum**)

2. molecule on which an enzyme acts

*NOTE In the language of cybernetics, the **substrate** is the operand, the enzyme (together with any **cofactors**) is the operator, and the product is the transform.*

2.67 substratum
surface on which material is deposited

2.68 superhydrophobic
has a water contact angle ideally equal to 180°, typically greater than 150°

*NOTE Such contact angles can be achieved by roughening the material's surface (see **lotus effect**).*

2.69 surface coating
deposit or deposition of material on bulk objects in order to modify their surfaces

2.70 surface engineering
processes separately applied to the surface of an object subsequent to the basic fabrication of the object, but excluding coatings

2.71 surface plasmon
collective oscillation of conduction band electrons in a thin metal film (whose frequency is susceptible to perturbation by nearby biomolecules)

*NOTE Also known as **surface plasmon** polaritons.*

2.72 surface plasmon resonance (SPR)
excitation of **surface plasmon** at its resonant frequency by an external electromagnetic wave; can be represented as a surface electromagnetic wave that propagates parallel along the metal/dielectric interface

2.73 textured surface
surface made chemically and/or topologically heterogeneous, possibly with structure identifiable at more than one distinct length scale

2.74 tissue scaffold
three dimensional material used to facilitate the proliferation, differentiation and migration of cells; used to replace, repair, or regenerate tissues

NOTE 1 Typically the scaffold is porous, but if the cells only grow on the surface, then it is a ***substrate*** *rather than scaffold.*

NOTE 2 The ASTM Designation is: three-dimensional material used as a support, delivery vehicle, or matrix for facilitating the proliferation, differentiation and migration of cells, used to replace, repair, or regenerate tissues.

[ASTM, Designation F2603-06. *Standards Guide for Interpreting Images of Polymeric Tissue Scaffolds* [7]]

2.75 transducer (in the context of biosensing)
that part of a biosensor, which relays the result of molecular recognition to the outside world

2.76 turnover
number of **substrate** molecules transformed into product molecules per enzyme molecule

2.77 zeta potential
electrostatic potential at the **slipping plane**

NOTE The electrokinetic or zeta potential measures the electrostatic potential at, or very near to, the beginning of the diffuse double layer.

3 Abbreviations

FCS Fluorescence Correlation Spectroscopy

FRET Fluorescence Resonance Energy Transfer

NEMS Nano Electro Mechanical System

OWLS Optical Waveguide Lightmode Spectroscopy

SPR Surface Plasmon Resonance

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.

PAS 71:2005, *Vocabulary – Nanoparticles*

ISO/TS 27687, *Terminology and definitions for nanoparticles*[2)]

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[7] ASTM International, Designation F2603-06. Standards Guide for Interpreting Images of Polymeric Tissue Scaffolds.

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*

2) In preparation.

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