

PAS 134:2012



BSI Standards Publication

Terminology for carbon nanostructures

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Summary of pages

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Foreword

Publishing information

This Publicly Available Specification (PAS) was commissioned by the Department for Business, Innovation and Skills (BIS) and its development was facilitated by the British Standards Institution (BSI). It came into effect on 23 March 2012.

Acknowledgement is given to the following organizations that were involved in the revision of this terminology as members of the Steering Group:

Cranfield University;

Ionbond UK Ltd;

National Physical Laboratory;

University of Cambridge.

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.

BSI retains ownership and copyright of this PAS. BSI reserves the right to withdraw or amend this PAS on receipt of authoritative advice that it is appropriate to do so. This PAS will be reviewed at intervals not exceeding two years, and any amendments arising from the review will be published as an amended PAS and publicized in *Update Standards*.

This PAS is not to be regarded as a British Standard. It will be withdrawn upon publication of its content in, or as, a British Standard.

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*.

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.

Compliance with a Publicly Available Specification cannot confer immunity from legal obligations.

Introduction

The first edition of this Publicly Available Specification (PAS) was, along with five other vocabulary documents, commissioned by the UK Department of Trade and Industry (DTI) in 2006 for the purposes of developing and encouraging the use of a common language relevant to nanotechnologies and nanomaterials. These PASs were intended to seed, and have seeded, further developments and discussions in formal standards-making. They have informed the preparation of other standards in this area.

Nanotechnologies are a group of emerging technologies, characterized by the “application of scientific knowledge to manipulate and control matter in the nanoscale in order to make use of size- and structure-dependent properties and phenomena, as distinct from those associated with individual atoms or molecules or with bulk materials” (see DD ISO TS 80004-1:2012, definition 2.3). These technologies are evolving quickly and will gain increasing importance over the next few years. Their application is expected to impact virtually all areas of human endeavour, in particular agriculture, construction, energy generation and storage, engineering, environmental remediation, healthcare, ICT, medicine and medical devices, pharmaceuticals, sustainability and transport.

This PAS was commissioned in response to demands by UK industry to provide standards to support future applications. The intention was to bring together the disparate terms and definitions relevant to carbon nanostructures and their production, measurement and characterization.

The principal difference between a PAS and a full British, European or international standard, is that a PAS is created in a consultative process across industry rather than gaining the full consensus of a specific technical committee.

The remit of this PAS is to document and, to a lesser degree, comment on the current use of basic carbon nanostructure terms and definitions in use by manufacturers, suppliers, academia, regulators and governments, and to make recommendations for usage as required. It also includes terms defining production methods and analytical techniques employed by those working with carbon nanomaterials.

Together with six related PAS vocabularies,¹⁾ PAS 134 has helped to stimulate international activity in the area being undertaken by a joint working group between ISO/TC 229, *Nanotechnologies*, and IEC/TC 113, *Nanotechnology standardization for electrical and electronic products and systems*. This activity has so far contributed to the publication of five internationally accepted vocabularies, the relevant output of which is reflected in this revision of PAS 134, in particular that contained in DD ISO TS 80004-3:2010, *Nanotechnologies – Vocabulary – Part 3: Carbon nano-objects*. While it was the intention to withdraw this PAS once equivalent full consensus international standards on the subject have been published, the scope of DD ISO TS 80004-3 is limited to terms specific to carbon nano-objects and does not include the wider remit of terms covered in the present document. Hence it was decided that PAS 134 should be revised to align relevant terms with the ISO documents but that it should be maintained until such time as its scope is completely addressed by other publications.

This PAS does not provide a nomenclature system for carbon nanostructures, as this is a specialized subject and there is no current consensus in the nanotechnologies or nanosciences communities on how to approach such a system for the collection of carbon nanostructures, although work has commenced in ISO/TC 229 on developing a framework for nomenclature models for nano-objects.

¹⁾ See www.bsigroup.com/nano

However, IUPAC²⁾ has developed a numbering system for one group of carbon nanostructures, the fullerenes [1], together with a nomenclature for a subset of these [2].

This vocabulary attempts not to include terms that are used in a manner consistent with a definition given in the *Oxford English Dictionary* [3], and terms that already have well established meanings 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 chemical and physical structure, characterization, functionalization, manufacture and synthesis of carbon nanostructures.

It is applicable to, but not limited to, diamond, graphite, fullerene, nanofibre, nanohorn, nanorod, nanotube and graphene structures.

This PAS is intended for use by technologists, 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 General terms referring to nano-objects

2.1 nanocone

cone-shaped **nanofibre** or **nanoparticle**

[DD ISO/TS 80004-3:2010, definition 2.9]

2.2 nanofibre

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

NOTE 1 A nanofibre can be flexible or rigid.

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 The largest external dimension is not necessarily in the nanoscale.

[DD CEN ISO/TS 27687:2009, definition 4.3]

2.3 nano-object

material with one, two or three external dimensions in the **nanoscale**

NOTE Generic term for all discrete nanoscale objects.

[DD CEN ISO/TS 27687:2009, definition 2.2]

2.4 nano-onion

spherical **nanoparticle** with concentric multiple shell structure

[DD ISO/TS 80004-3:2010, definition 2.8]

²⁾ International Union of Pure and Applied Chemistry.

2.5 nanoparticle

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

NOTE 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** or **nanoplate** are intended to be used instead of the term **nanoparticle**.

[DD CEN ISO/TS 27687:2009, definition 4.1]

2.6 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 in the **nanoscale**.

[DD CEN ISO/TS 27687:2009, definition 4.2]

2.7 nanoribbon

nanoplate with one of its two larger dimensions in the **nanoscale** and the other significantly larger

[DD ISO/TS 80004-3:2010, definition 2.10]

2.8 nanorod

solid **nanofibre**

[DD CEN ISO/TS 27687:2009, definition 4.5]

2.9 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.

[DD CEN ISO/TS 27687:2009, definition 2.1]

2.10 nanotube

hollow **nanofibre**

[DD CEN ISO/TS 27687:2009, definition 4.4]

3 General terms relevant to carbon chemistry and carbon nanostructures

3.1 carbon hybridization

merging of the outer *s* and *p* orbitals in carbon atoms

NOTE Carbon has four valence electrons. In an isolated carbon atom, two of the valence electrons are expected to be in the 2*s* orbital and the other two to be in two of the three 2*p* orbitals. However, depending on the local conditions, one of the 2*s* electrons may move to the third 2*p* orbital allowing the 2*s* to merge with the 2*p* and form new kinds of orbital called *sp*. Even though the *s* and *p* orbitals are symmetric with respect to the nucleus of the carbon atom, the *sp* orbitals are highly directional and most of the electron cloud exists on one side of the carbon nucleus. *sp*¹, *sp*² and *sp*³ below are used to denote the different possible hybridizations in carbon.