
Nanotechnologies — Vocabulary —
Part 3:
Carbon nano-objects

Nanotechnologies — Vocabulaire —
Partie 3: Nano-objets carbonés

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

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This second edition cancels and replaces the first edition (ISO/TS 80004-3:2010), which has been technically revised throughout.

A list of all parts in the ISO/TS 80004 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

In the last three decades, various new forms of nanoscale carbon materials, including fullerenes, graphene and carbon nanotubes, have been discovered, synthesized and manufactured. These are promising materials for many industrial fields associated with nanotechnologies because of their unique electronic, electromagnetic, thermal, optical and mechanical properties.

In the context of increasing scientific knowledge and a growing number of technical terms in the field of nanotechnologies (see the Bibliography), the purpose of this document is to define important terms and concepts for carbon nano-objects in a precise and consistent manner, while clarifying their interrelationship, as well as their relationship, to existing terms previously used for conventional carbon materials.

This document belongs to a multi-part vocabulary covering the different aspects of nanotechnologies. Most of the definitions in this document are deliberately determined so as to be in harmony with a rational hierarchical system of terminology under development for nanotechnologies, although in some cases the hierarchical approach needs to be compromised due to the specific usage of individual terms. ISO/TS 80004-13 further complements this document by providing terms and definitions for graphene and related two-dimensional (2D) materials. A subset of these terms is only noted herein.

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Nanotechnologies — Vocabulary —

Part 3: Carbon nano-objects

1 Scope

This document defines terms related to carbon nano-objects in the field of nanotechnologies.

It is intended to facilitate communication between organizations' and individuals' research, industry and other interested parties and those who interact with them. Additional terms and definitions for graphene and two-dimensional materials (2D) materials are provided in ISO/TS 80004-13.

Related carbon nanoscale materials are given in [Annex A](#).

2 Normative references

There are no normative references in this document.

3 Terms and definitions

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

3.1 Basic terms used in the description of carbon nano-objects

3.1.1

nanoscale

length range approximately from 1 nm to 100 nm

Note 1 to entry: Properties that are not extrapolations from a larger size are predominantly exhibited in this length range.

[SOURCE: ISO/TS 80004-1:2015, 2.1]

3.1.2

nanomaterial

material with any external dimension in the *nanoscale* ([3.1.1](#)) or having internal structure or surface structure in the nanoscale

Note 1 to entry: This generic term is inclusive of *nano-object* ([3.1.3](#)) and *nanoscale material* ([3.1.4](#)).

Note 2 to entry: See also “engineered nanomaterial”, “manufactured nanomaterial” and “incidental nanomaterial”.

[SOURCE: ISO/TS 80004-1:2015, 2.4]

3.1.3

nano-object

discrete piece of material with one, two or three external dimensions in the *nanoscale* ([3.1.1](#))

Note 1 to entry: The second and third external dimensions are orthogonal to the first dimension and to each other.

[SOURCE: ISO/TS 80004-1:2015, 2.5]

3.1.4

nanostuctured material

material having internal nanostructure or surface nanostructure

Note 1 to entry: This definition does not exclude the possibility for a *nano-object* (3.1.3) to have internal structure or surface structure. If external dimension(s) are in the *nanoscale* (3.1.1), the term “nano-object” is recommended.

[SOURCE: ISO/TS 80004-1:2015, 2.7]

3.1.5

nanoparticle

nano-object (3.1.3) with all external dimensions in the *nanoscale* (3.1.1) where the lengths of the longest and the shortest axes of the nano-object do not differ significantly

Note 1 to entry: If the dimensions differ significantly (typically by more than three times), terms such as *nanofibre* (3.1.7) or *nanoplate* (3.1.6) may be preferred to the term “nanoparticle”.

[SOURCE: ISO/TS 80004-2:2015, 4.4]

3.1.6

nanoplate

nano-object (3.1.3) with one external dimension in the *nanoscale* (3.1.1) and the other two external dimensions significantly larger

Note 1 to entry: The larger external dimensions are not necessarily in the nanoscale.

Note 2 to entry: See 3.1.3, Note 1 to entry. The smallest external dimension is the thickness of the nanoplate.

[SOURCE: ISO/TS 80004-2:2015, 4.6, modified —Note 2 to entry has been replaced.]

3.1.7

nanofibre

nano-object (3.1.3) with two external dimensions in the *nanoscale* (3.1.1) and the third dimension significantly larger

Note 1 to entry: The largest external dimension is not necessarily in the nanoscale.

Note 2 to entry: The terms “nanofibril” and “nanofilament” can also be used.

Note 3 to entry: See 3.1.3, Note 1 to entry. Nano-object with two similar external dimensions in the nanoscale and the third dimension significantly larger.

[SOURCE: ISO/TS 80004-2:2015, 4.5, Note 3 to entry has been replaced.]

3.1.8

nanotube

hollow *nanofibre* (3.1.7)

[SOURCE: ISO/TS 80004-2:2015, 4.8]

3.1.9

nanorod

solid *nanofibre* (3.1.7)

[SOURCE: ISO/TS 80004-2:2015, 4.7]

3.1.10

nano-onion

spheroidal *nanoparticle* (3.1.5) with a concentric multiple shell structure

3.1.11**nanocone**

cone-shaped *nanofibre* (3.1.7) or *nanoparticle* (3.1.5)

3.1.12**nanoribbon**

nanotape

nanoplate (3.1.6) with the two larger dimensions significantly different from each other

Note 1 to entry: See 3.1.3, Note 1 to entry.

[SOURCE: ISO/TS 80004-2:2015, 4.10]

3.1.13**graphene**

monolayer graphene

single-layer graphene

single *layer* (3.1.15) of carbon atoms with each atom bound to three neighbours in a honeycomb structure

Note 1 to entry: It is an important building block of many carbon *nano-objects* (3.1.3).

Note 2 to entry: As graphene is a single layer, it is also sometimes called “monolayer graphene” or “single-layer graphene” and abbreviated as “1LG” to distinguish it from *bilayer graphene* (2LG) (3.1.17) and *few-layer graphene* (FLG) (3.1.18).

Note 3 to entry: Graphene has edges and can have defects and grain boundaries where the bonding is disrupted.

[SOURCE: ISO/TS 80004-13:2017, 3.1.2.1]

3.1.14**graphite**

allotropic form of the element carbon, consisting of *graphene* (3.1.13) layers stacked parallel to each other in a three-dimensional, crystalline, long-range order

Note 1 to entry: Adapted from the definition in the IUPAC *Compendium of Chemical Terminology*^[6].

Note 2 to entry: There are two primary allotropic forms with different stacking arrangements: hexagonal and rhombohedral.

[SOURCE: ISO/TS 80004-13:2017, 3.1.2.2]

3.1.15**layer**

discrete material restricted in one dimension, within or at the surface of a condensed phase

[SOURCE: ISO/TS 80004-11:2017, 3.1.2]

3.1.16**two-dimensional material****2D material**

material, consisting of one or several *layers* (3.1.15) with the atoms in each layer strongly bonded to neighbouring atoms in the same layer, which has one dimension, its thickness, in the *nanoscale* (3.1.1) or smaller and the other two dimensions generally at larger scales

Note 1 to entry: The number of layers when a two-dimensional material becomes a bulk material varies depending on both the material being measured and its properties. In the case of *graphene* (3.1.13), it is a two-dimensional material up to 10 layers thick for electrical measurements^[2], beyond which the electrical properties of the material are not distinct from those for the bulk [also known as *graphite* (3.1.14)].

Note 2 to entry: Interlayer bonding is distinct from and weaker than intralayer bonding.

Note 3 to entry: Each layer may contain more than one element.

Note 4 to entry: A two-dimensional material can be a *nanoplate* (3.1.6).

[SOURCE: ISO/TS 80004-13:2017, 3.1.1.1]

3.1.17

bilayer graphene

2LG

two-dimensional material (3.1.16) consisting of two well-defined stacked *graphene* (3.1.13) layers

Note 1 to entry: If the stacking registry is known, it can be specified separately, for example, as “Bernal stacked bilayer graphene”.

[SOURCE: ISO/TS 80004-13:2017, 3.1.2.6]

3.1.18

few-layer graphene

FLG

two-dimensional material (3.1.16) consisting of three to ten well-defined stacked *graphene* (3.1.13) layers

[SOURCE: ISO/TS 80004-13:2017, 3.1.2.10]

3.1.19

aciniform

object or structure having a shape consistent with grape-like clusters

Note 1 to entry: Aciniforms are often composed of *nodules* (3.1.20) or particles.

3.1.20

nodule

rounded or irregular shaped feature distinct from its surroundings

Note 1 to entry: Nodules do not have discrete boundaries at the attachment point with the object.

3.1.21

de Broglie wavelength

wavelength of the wave associated with any particle which reflects its wave nature according to de Broglie's formula

Note 1 to entry: De Broglie's formula is:

$$\lambda = h/p$$

where

λ is the wavelength;

h is the Planck's constant;

p is the particle momentum.

[SOURCE: ISO/TS 80004-12:2016, 2.1]

3.1.22

quantum confinement

restriction of a particle's motion in one, two or three space dimensions when the size of a physical system is of the same order of magnitude as the particle's *de Broglie wavelength* (3.1.21)

Note 1 to entry: The main characteristic lengths leading to quantum confinement may be their de Broglie wavelength, their Fermi wavelength, their mean free path, their Bohr radius (for excitons) or their coherence length.

Note 2 to entry: See Reference [8].

[SOURCE: ISO/TS 80004-12:2016, 2.5]

3.1.23

quantum dot

QD

nanoparticle (3.1.5) or region which exhibits *quantum confinement* (3.1.22) in all three spatial directions.

Note 1 to entry: See References [8] to [12].

[SOURCE: ISO/TS 80004-12:2016, 4.1]

3.2 Terms describing specific types of carbon nanoparticles

3.2.1

fullerene

molecule composed solely of an even number of carbon atoms, which form a closed cage-like fused-ring polycyclic system with 12 five-membered rings and the rest six-membered rings

Note 1 to entry: Adapted from the definition in the IUPAC *Compendium of Chemical Terminology* [6].

Note 2 to entry: A well-known example is C₆₀, which has a spherical shape with an external dimension of about 1 nm.

3.2.2

fullerene derivative

compound that has been formed from *fullerene* (3.2.1) by substitution of carbon or covalent attachment of a moiety

3.2.3

endohedral fullerene

fullerene (3.2.1) with an additional atom or atoms enclosed within the fullerene shell

3.2.4

metallofullerene

endohedral fullerene (3.2.3) with an enclosed metal ion or ions

3.2.5

carbon nano-onion

nano-onion (3.1.10) composed of carbon

3.3 Terms describing specific types of carbon nanofibres and nanoplates

3.3.1

carbon nanofibre

CNF

nanofibre (3.1.7) composed of carbon

3.3.2

graphite nanofibre

carbon nanofibre (3.3.1) composed of *graphite* (3.1.14) multilayer structures

Note 1 to entry: Graphite layers can be any orientation with respect to the fibre axis without long-range order.

3.3.3

carbon nanotube

CNT

nanotube (3.1.8) composed of carbon

Note 1 to entry: Carbon nanotubes usually consist of curved *graphene* (3.1.13) layers, including *single-walled carbon nanotubes* (3.3.4) and *multi-walled carbon nanotubes* (3.3.6).

3.3.4

single-walled carbon nanotube

SWCNT

single-wall carbon nanotube

carbon nanotube (3.3.3) consisting of a single cylindrical *graphene* (3.1.13) layer

Note 1 to entry: The structure can be visualized as a graphene sheet rolled into a cylindrical honeycomb structure.

3.3.5

chiral vector of single-walled carbon nanotube

chiral vector of SWCNT

vector notation used to describe the helical structure of a *single-walled carbon nanotube* (3.3.4)

3.3.6

multi-walled carbon nanotube

MWCNT

multiwall carbon nanotube

carbon nanotube (3.3.3) composed of nested, concentric or near-concentric *graphene* (3.1.13) layers with interlayer distances similar to those of *graphite* (3.1.14)

Note 1 to entry: The structure is normally considered to be many *single-walled carbon nanotubes* (3.3.4) nesting each other, and would be cylindrical for small diameters but tends to have a polygonal cross-section as the diameter increases.

3.3.7

double-walled carbon nanotube

DWCNT

double-wall carbon nanotube

multi-walled carbon nanotube (3.3.6) composed of only two nested, concentric *single-walled carbon nanotubes* (3.3.4)

Note 1 to entry: Although this is a type of multi-walled carbon nanotube, its properties are rather closer to a single-walled carbon nanotube.

3.3.8

carbon nanopeapod

linear array of *fullerenes* (3.2.1) enclosed in a *carbon nanotube* (3.3.3)

Note 1 to entry: This is an example of a composite *nanofibre* (3.1.7).

3.3.9

carbon nanohorn

short and irregular-shaped *carbon nanotube* (3.3.3) with a *nancone* (3.1.11) apex

Note 1 to entry: Usually hundreds of carbon nanohorns constitute an aggregate *nanoparticle* (3.1.5).

3.3.10

carbon nanoribbon

nanoribbon (3.1.12) composed of carbon

Note 1 to entry: Carbon nanoribbons are often in the form of multiple layers of *graphene* (3.1.13). In the case of a single graphene layer, the term "graphene ribbon" is used.

3.3.11

carbon quantum dot

carbon dot

quantum dot (3.1.23) composed of carbon

3.4 Terms describing nanostructured carbon nano-objects

3.4.1

soot

carbonaceous material produced by the incomplete and uncontrolled combustion of organic matter and, as such, having varying morphologies and limited uniformity within a given aggregate

Note 1 to entry: It is typically comprised of elemental carbon (this can vary from high 90 % to around 60 %), with remainder of organic and inorganic residue.

Note 2 to entry: Soot can be comprised of objects larger than the *nanoscale* (3.1.1).

Note 3 to entry: Soot can contain *aciniform* (3.1.19) material.

3.4.2

carbon black

industrially engineered *aciniform* (3.1.19) elemental carbonaceous material, produced from the partial combustion of hydrocarbons

Note 1 to entry: Discrete particles exist as aggregates or clustered *nodules* (3.1.20).

Note 2 to entry: Carbon black can be comprised of objects larger than the *nanoscale* (3.1.1).

Note 3 to entry: Discrete particles of carbon black are frequently larger than the nanoscale.

Note 4 to entry: Carbon black typically consists of more than 95 % elemental carbon.

Annex A **(informative)**

Related carbon nanoscale materials

A.1 General

There are many kinds of conventional carbon materials that have been produced and used widely in industry for many years. Some of them may fall into the category of nanotechnologies in view of substantial recent progress in controlling their nanoscale dimensions. However, the terms associated with them are viewed as satisfactory at this time and need not be redefined in this document.

A.2 Diamond nanoparticles and related structures

Diamond nanoparticles (often called “nanodiamond”) are related to a large group of carbon materials with very different production methods (e.g. explosive methods, chemical vapour deposition, physical vapour deposition), appearance, size, properties and application. Some diamond-based nanoparticles, such as diamondoids, occur naturally and can be extracted from hydrocarbon deposits. Some of the terms and definitions associated with diamond nanoparticles are listed in BS PAS 134:2007^[13].

A.3 Carbon films

Carbon films have been used commercially in the coatings industry to impart certain properties to materials. Carbon films can be produced using a variety of different techniques, such as cathodic arc and magnetron sputtering. There are various terms used in the literature for carbon-based coatings, e.g. diamond-like carbon (DLC), glassy carbon and tetrahedral amorphous carbon. Basically, these films differ by the various fractions of sp^2 , sp^3 hybridization and hydrogen content within them. For example, diamond-like carbon is typically used to reduce abrasive wear, while glassy carbon is used where resistance to high temperatures, chemical attack and gas or liquid impermeability is required. Some of the terms and definitions associated with carbon films are listed in BS PAS 134:2007^[13].