TECHNICAL SPECIFICATION

ISO/TS 80004-8

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Nanotechnologies — Vocabulary —

Part 8: Nanomanufacturing processes

Nanotechnologies — Vocabulaire —

Partie 8: Processus de nanofabrication

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Foreword

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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. www.iso.org/directives

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

ISO/TS 80004-8 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*.

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*

— *Part 12: Quantum phenomena in nanotechnology*

1) Revises and replaces ISO/TS 27687[5].

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Graphene and other two-dimensional materials is to form the subject of a future part 13.

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Introduction

Nanomanufacturing is the essential bridge between the discoveries of the nanosciences and real-world nanotechnology products.

Advancing nanotechnology from the laboratory into volume production ultimately requires careful study of manufacturing process issues including product design, reliability and quality, process design and control, shop floor operations, supply chain management, workplace safety and health practices during the production, use, and handling of nanomaterials. Nanomanufacturing encompasses directed self assembly and assembly techniques, synthetic methodologies, and fabrication processes such as lithography and biological processes. Nanomanufacturing also includes bottom-up directed assembly, top-down high resolution processing, molecular systems engineering, and hierarchical integration with larger scale systems. As dimensional scales of materials and molecular systems approach the nanoscale, the conventional rules governing their behaviour may change significantly. As such, the behaviour of a final product is enabled by the collective performance of its nanoscale building blocks.

Biological process terms are not included in this first edition of the nanomanufacturing vocabulary, but considering the rapid development of the field, it is expected that terms in this important area will be added in a future update to this Technical Specification or in companion documents in the 80004 series. This could include both the processing of biological nanomaterials and the use of biological processes to manufacture materials at the nanoscale.

Similarly, additional terms from other developing areas of nanomanufacturing, including composite manufacturing, roll-to-roll manufacturing, and others, will be included in future documents.

There is a distinction between the terms nanomanufacturing and nanofabrication. Nanomanufacturing encompasses a broader range of processes than does nanofabrication. Nanomanufacturing encompasses all nanofabrication techniques and also techniques associated with materials processing and chemical synthesis.

This document provides an introduction to processes used in the early stages of the nanomanufacturing value chain, namely the intentional synthesis, generation or control of nanomaterials, including fabrication steps in the nanoscale. The nanomaterials that result from these manufacturing processes are distributed in commerce where, for example, they may be further purified, be compatabilized to be dispersed in mixtures or composite matrices, or serve as integrated components of systems and devices. The nanomanufacturing value chain is, in actuality, a large and diverse group of commercial value chains that stretch across these sectors:

— the semiconductor industry (where the push to create smaller, faster, and more efficient microprocessors heralded the creation of circuitry less than 100 nm in size);

— electronics and telecommunications;

— aerospace, defence, and national security;

— energy and automotive;

— plastics and ceramics;

— forest and paper products;

— food and food packaging;

— pharmaceuticals, biomedicine, and biotechnology;

— environmental remediation;

— clothing and personal care.

There are thousands of tonnes of nanomaterials on the market with end use applications in several of these sectors, such as carbon black and fumed silica. Nanomaterials which are rationally designed with

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specific purpose are expected to radically change the landscape in areas such as biotechnology, water purification, and energy development.

The majority of sections in this document are organized by process type. In the case of section 6, the logic of placement is as follows: in the step before the particle is made, the material itself is in a gas/liquid/solid phase. The phase of the substrate or carrier in the process does not drive the categorization of the process. As an example, consider iron particles that are catalysts in a process by which you seed oil with iron particles, the oil vaporizes and condenses forming carbon particles on the iron particles. What vaporizes is the oil, and therefore it is a gas phase process. Nanotubes grown from the gas phase, starting with catalyst particles that react with the gas phase to grow the nanotubes, thus this is characterized as a gas process. Indication of whether synthesis processes are used to manufacture nano-objects, nanoparticles, or both, is provided in Annex A.

A common understanding of the terminology used in practical applications will enable communities of practice in nanomanufacturing and will advance nanomanufacturing strength worldwide. Extending the understanding of terms across the existing manufacturing infrastructure will serve to bridge the transition between the innovations of the research laboratory and the economic viability of nanotechnologies.

For informational terms supportive of nanomanufacturing terminology, see Reference [1].

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Nanotechnologies — Vocabulary —

Part 8: Nanomanufacturing processes

1 Scope

This Technical Specification gives terms and definitions related to nanomanufacturing processes in the field of nanotechnologies. It forms one part of multi-part terminology and definitions documentation covering the different aspects of nanotechnologies.

All the process terms in this document are relevant to nanomanufacturing. Many of the listed processes are not exclusively relevant to the nanoscale. Depending on controllable conditions, such processes may result in material features at the nanoscale or, alternatively, larger scales.

There are many other terms that name tools, components, materials, systems control methods or metrology methods associated with nanomanufacturing that are beyond the scope of this document.

2 Terms and definitions from other parts of ISO/TS 80004

The terms and definitions in this clause are given in other parts of ISO/TS 80004. They are reproduced here for context and better understanding.

2.1
carbon nanotube
CNT
nanotube (2.9) composed of carbon

Note 1 to entry: carbon nanotubes usually consist of curved graphene layers, including single-wall carbon nanotubes and multiwall carbon nanotubes.

[SOURCE: ISO/TS 80004-3:2010, 4.3.]

2.2
nanocomposite
solid comprising a mixture of two or more phase-separated materials, one or more being nanophase

Note 1 to entry: Gaseous nanophases are excluded (they are covered by nanoporous material).

Note 2 to entry: Materials with *nanoscale* (2.7) phases formed by precipitation alone are not considered to be nanocomposite materials.

[SOURCE: ISO/TS 80004-4:2011, 3.2.]

2.3
nanofibre
nano-object with two similar external dimensions in the *nanoscale* (2.7) 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* (2.7).

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[SOURCE: ISO/TS 27687:2008, 4.3.]

2.4
nanomaterial
material with any external dimension in the *nanoscale* (2.7) or having internal structure or surface structure in the nanoscale

Note 1 to entry: This generic term is inclusive of *nano-object* (2.5) and *nanostructured material* (2.9).

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

[SOURCE: ISO/TS 80004-1:2010, 2.4.]

2.5
nano-object
material with one, two or three external dimensions in the *nanoscale* (2.7)

Note 1 to entry: Generic term for all discrete nano-objects.

[SOURCE: ISO/TS 80004-1:2010, 2.5.]

2.6
nanoparticle
nano-object (2.5) with all three external dimensions in the *nanoscale* (2.7)

Note 1 to entry: if the lengths of the longest to the shortest axes of the *nano-object* (2.5) differ significantly (typically by more than three times), the terms *nanofibre* (2.3) or nanoplate are intended to be used instead of the term nanoparticle.

[SOURCE: ISO/TS 27687:2008, 4.1.]

2.7
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* (2.5) or elements of nanostructures, which might be implied by the absence of a lower limit.

[SOURCE: ISO/TS 80004-1:2010, 2.1.]

2.8
nanostructured material
material having internal or surface structure in the *nanoscale* (2.7)

Note 1 to entry: If external dimensions are in the nanoscale, the term *nano-object* (2.4) is recommended.

Note 2 to entry: Adapted from ISO/TS 80004-1:2010, definition 2.7.

[SOURCE: ISO/TS 80004-4, 2.11.]

2.9
nanotube
hollow *nanofibre* (2.3)

[SOURCE: ISO/TS 27687:2008, 4.4]

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3 General terms

3.1
bottom up nanomanufacturing
processes that use small fundamental units in the *nanoscale* (2.7) to create larger functionally rich structures or assemblies

3.2
co-deposition
simultaneous deposition of two or more source materials

Note 1 to entry: Common methods include vacuum, thermal spray, electrodeposition and liquid suspension deposition techniques.

3.3
communition
crushing or grinding for particle size reduction

3.4
directed assembly
<nanotechnologies> formation of a structure guided by external intervention using components at the *nanoscale* (2.7) that can, in principle, have any defined pattern

3.5
directed self-assembly
self-assembly (3.11) influenced by external intervention to produce a preferred structure, orientation or pattern

Note 1 to entry: Examples of external intervention include an applied field, a chemical or structural template, chemical gradient, and fluidic flow.

3.6
lithography
reproducible creation of a pattern

Note 1 to entry: The pattern can be formed in a radiation sensitive material or by transfer of material onto a substrate either by transfer, by printing or by direct writing.

3.7
multilayer deposition
alternating deposition of two or more source materials to produce a composite layer structure

3.8
nanofabrication
ensemble of activities to intentionally manufacture devices in the *nanoscale* (2.7), for commercial purpose

3.9
nanomanufacturing
intentional synthesis, generation or control of nanomaterials, or fabrication steps in the *nanoscale* (2.7), for commercial purpose

[SOURCE: ISO/TS 80004-1:2010, definition 2.11.]

3.10
nanomanufacturing process
ensemble of activities to intentionally synthesize, generate or control *nanomaterials* (2.4), or fabrication steps in the *nanoscale* (2.7), for commercial purpose

[SOURCE: ISO/TS 80004-1:2010, 2.12.]

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