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Nanotechnologies — Vocabulary for cellulose nanomaterial

Nanotechnologies — Vocabulaire pour les nanomatériaux à base de cellulose

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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 document 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.

This document was prepared by Technical Committee ISO/TC 229, *Nanotechnologies*.

This second edition cancels and replaces the first edition (ISO/TS 20477:2017), which has been technically revised.

The main changes are as follows:

— some existing definitions have been revised;

— new terms and definitions have been introduced;

— micrographic images of cellulose nanomaterials have been introduced to illustrate some of the defined terms.

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

Cellulose is a polymer produced in nature. In plants, animals, algae and bacteria, cellulose is extruded from terminal enzyme complexes (TC). TCs are made up of many identical subunits, each containing at least one catalytic site from which a single cellulose chain is synthesized. Cellulose chains from a single TC combine to form an elementary fibril. As TCs in plants, animals, algae and bacteria have different numbers and configurations of subunits, the elementary fibrils they produce have different geometries.[1] Whether cellulose nanomaterials are separated by industrial processes or produced directly by organisms, they all contain a common structural component, which is the elementary fibril. This common component, the elementary fibril, provides a way to describe cellulose nanomaterials from all manufacturing methods and cellulose sources.

Cellulose nanomaterials can be manufactured industrially by conversion of wood pulp through chemical, biological or mechanical processes. Bacterium-based cellulose nanomaterials are produced directly by bacteria and can be further acid-hydrolysed to smaller dimensions. Besides trees and bacteria, algae are another potential source of cellulose nanomaterials for industrial applications. Owing to their unique properties and renewable nature, cellulose nanomaterials have developed into platform materials that have application potential in a wide range of products including those that currently utilize petroleum-based ingredients.

At the current stage of development, several terms that describe cellulose nanomaterials coexist and have created confusion among users. The difficulty of measuring sizes in the low micrometre and nanometre scale has given rise to confusion in the classification of materials, particularly for the fibrillate materials. Rather than delaying standards development until knowledge accumulated with research advancement and market maturity, there is an opportunity to define a standard vocabulary for cellulose nanomaterials, and for clarity, describe micro-scale cellulose materials, as given in Annex B. Although terms in the ISO/IEC 80004 series were not developed for specific types of nanomaterials such as cellulose nanomaterials, to be consistent with existing ISO/TC 229 hierarchy, this document utilizes terms from the ISO/IEC 80004 series. It is anticipated that as the market for cellulose nanomaterials matures, so too will the standard vocabulary. Beginning to define a standard vocabulary now will facilitate future communication, eliminate confusion, remove trade barriers, and provide policy makers and regulators with a set of consensus-based terms.

Nanotechnologies — Vocabulary for cellulose nanomaterial

1 Scope

This document defines terms and definitions for different types of cellulose nanomaterials including secondary components found in cellulose nanomaterials originating from their manufacturing processes. This document also provides information on cellulose micromaterials in Annex B.

Where necessary, terms from the ISO/IEC 80004 series are included in this document. Terms in this document are applicable to all types of cellulose nanomaterials, regardless of production methods and their origin (plants, animals, algae or bacteria).

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1 Core nanotechnology terms related to cellulose nanomaterials

3.1.1
nanoscale
length range approximately from 1 nm to 100 nm

Note 1 to entry: Properties that are not extrapolations from larger sizes 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 *nanostructured material* (3.1.5).

Note 2 to entry: See also definitions of engineered nanomaterial, manufactured nanomaterial and incidental nanomaterial in ISO/TS 80004-1:2015.

[SOURCE: ISO/TS 80004-1:2015, 2.4, modified — Note 2 to entry has been added.]

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
nanostructure
composition of inter-related constituent parts in which one or more of those parts is a *nanoscale* (3.1.1) region

Note 1 to entry: A region is defined by a boundary representing a discontinuity in properties.

[SOURCE: ISO/TS 80004-1:2015, 2.6]

3.1.5
nanostructured material
material having internal *nanostructure* (3.1.4) 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]

3.1.6
nanofibre
nano-object (3.1.3) with two similar 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: Nanofibril and nanofilament are alternative terms for nanofibre.

Note 3 to entry: See Note 1 to entry of nanoparticle in ISO/TS 80004-2:2015.

[SOURCE: ISO/TS 80004-2:2015, 4.5]

3.1.7
nanocrystal
nano-object (3.1.3) with a *crystalline* (3.2.1) structure

[SOURCE: ISO/TS 80004-2:2015, 4.15]

3.2 Prerequisite non-nanotechnology terms related to cellulose nanomaterials

3.2.1
crystalline
having a solid structure with a three-dimensional arrangement of ions, molecules or atoms with long range order

3.2.2
paracrystalline
having short- and medium-range ordered lattice structure and lacking long-range order in at least one direction; in the intermediate state between *crystalline* (3.2.1) and amorphous

3.2.3
cellulose
linear polymeric chains of β (1→4) linked D-glucopyranose units

3.2.4
elementary fibril
structure originating from a single terminal enzyme complex and having a configuration of cellulose chains specific to each cellulose-producing plant, animal, algal and bacterial species

3.2.5
hemicellulose
non-cellulose heteropolysaccharides in organisms, typically containing monomers such as, but not limited to, xylose, glucose, mannose, galactose, arabinose and glucuronic acid

Note 1 to entry: Hemicellulose can be composed of branched polymers.

Note 2 to entry: Hemicellulose is usually extractable with dilute alkaline solutions.

3.3 Terms related specifically to cellulose nanomaterials

3.3.1
cellulose nanomaterial
CNM
nanocellulose
NC
cellulosic nanomaterial
CNM
material composed predominantly of *cellulose* (3.2.3), with any external dimension in the *nanoscale* (3.1.1), or a material having internal structure or surface structure in the nanoscale, with the internal structure or surface structure composed predominantly of cellulose

Note 1 to entry: Some cellulose nanomaterials can be composed of chemically modified cellulose.

Note 2 to entry: This term is inclusive of *cellulose nano-object* (3.3.2) and *cellulose nanostructured material* (3.3.3).

3.3.2
cellulose nano-object
nano-object (3.1.3) composed predominantly of *cellulose* (3.2.4)

3.3.3
cellulose nanostructured material
nanostructured material (3.1.5) of which the internal or surface *nanostructure* (3.1.4) is predominantly composed of *cellulose* (3.2.3)

3.3.4
cellulose nanofibre
nanofibre (3.1.6) composed predominantly of *cellulose* (3.2.3)

Note 1 to entry: This definition is a description of the morphology and the size of an object. It should not be confused with wood fibres or wood pulp fibres which typically have diameters of tens of micrometres.

3.3.5
cellulose nanocrystal
CNC
nanocrystal (3.1.7) composed predominantly of *cellulose* (3.2.3) containing predominantly *crystalline* (3.2.1) and *paracrystalline* (3.2.2) regions, with at least one *elementary fibril* (3.2.4), not exhibiting longitudinal splits

Note 1 to entry: The aspect ratio of cellulose nanocrystals is usually smaller than 50 but usually greater than 5, where aspect ratio refers to the ratio of the longest to the shortest dimensions.

Note 2 to entry: Cellulose nanocrystals do not exhibit interparticle entanglement or network-like structures.

Note 3 to entry: Historically cellulose nanocrystals have been called nanocrystalline cellulose (NCC) and whiskers such as cellulose nanowhiskers (CNW); they have also been called spheres, needles or nanowires based on their shape, dimensions and morphology; other names have included cellulose micelles, cellulose crystallites and cellulose microcrystals.

Note 4 to entry: See Figure A.1 for images of CNC.

3.3.6
cellulose nanofibril
CNF
cellulose (3.2.3) *nanofibre* (3.1.6) composed of at least one *elementary fibril* (3.2.4) that can contain branches a significant fraction of which are in the nanoscale

Note 1 to entry: The dimensions are typically 3 nm to 100 nm in cross-section and typically up to 100 µm in length.

Note 2 to entry: CNF can form entanglements between particles or network-like structure when the distance between CNF fibres is sufficiently close.

Note 3 to entry: Cellulose nanofibrils from plant sources, produced by mechanical processes, can be accompanied by *hemicellulose* (3.2.5), and in some cases lignin.

Note 4 to entry: Some cellulose nanofibrils can have functional groups on their surface as a result of the manufacturing process.

Note 5 to entry: The terms nanofibrillated cellulose (NFC), nanofibrillar cellulose (NFC), and *cellulose nanofibre* (3.3.4) have been used interchangeably with cellulose nanofibril. The terms microfibrillated cellulose (MFC), microfibrillar cellulose (MFC), cellulose microfibril (CMF) have also incorrectly been used to describe cellulose nanofibrils. To provide clarity, cellulose micromaterials are described in Annex B.

Note 6 to entry: The term cellulose nanoribbon has been used to describe cellulose nanofibrils from bacterial sources.

Note 7 to entry: See Figure A.2 for images of CNF.

3.3.7
individualized cellulose nanofibril
iCNF
discrete *cellulose nanofibril* (3.3.6) composed of one *elementary fibril* (3.2.4) with ionic functional groups on its surface

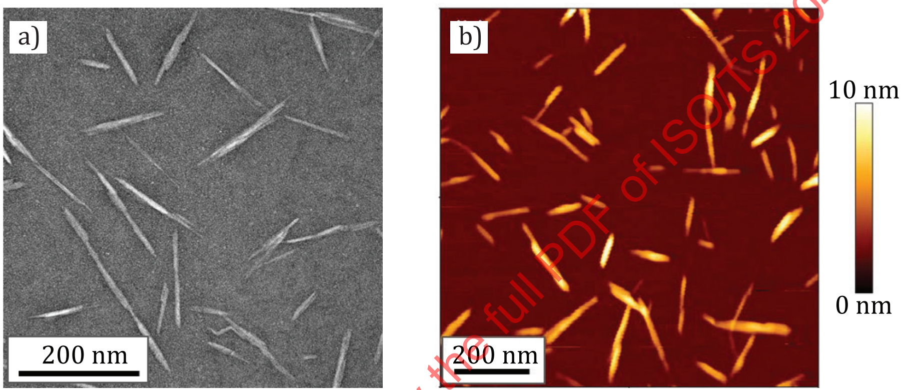
Note 1 to entry: See Figure A.3 for images of iCNF.

Annex A
(informative)

Images of cellulose nanomaterials

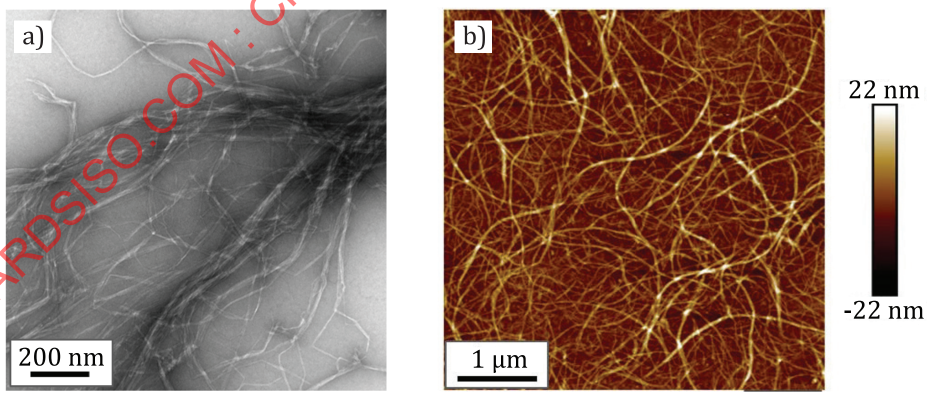
Images of CNC (Figure A.1), CNF (Figure A.2) and iCNF (Figure A.3) are presented in this annex to illustrate 3.3.5, 3.3.6 and 3.3.7, respectively.

It should be noted that, when imaging CNMs, there will be variability. The size of individual CNCs and CNFs and the level of aggregation or entanglement will vary depending on the cellulose biomass source, conditions used to prepare the initial material and the method used to deposit the sample for imaging.



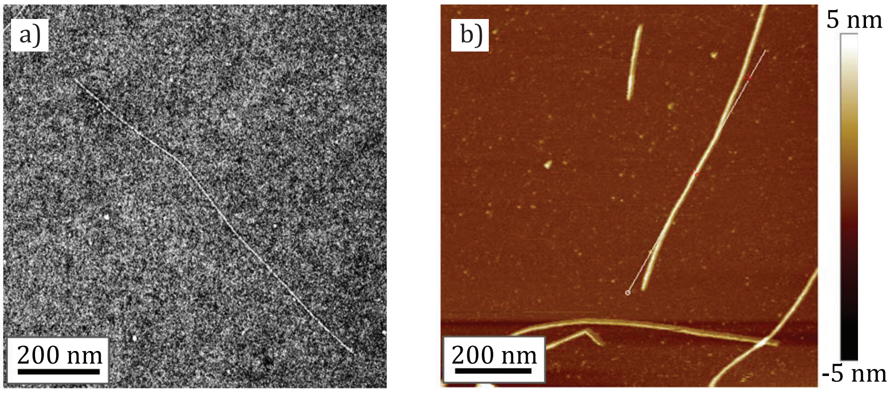
SOURCE Images provided by Dr. Linda Johnston, National Research Council Canada.

Figure A.1 — Representative images of CNCs measured by a) TEM and b) AFM



SOURCE TEM image provided by Dr. Ulrich Baxa, National Cancer Institute, USA and AFM image provided by Dr. Katariina Solin, VTT Technical Research Centre of Finland Ltd.

Figure A.2 — Representative images of CNFs measured by a) TEM and b) AFM



SOURCE Images provided by Professor Akira Isogai, the University of Tokyo.

Figure A.3 — Representative images of iCNFs measured by a) TEM and b) AFM

