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Nanotechnologies — Standard terms and their definition for cellulose nanomaterial

Termes normalisés et leur définition pour les nanomatériaux à base de cellulose

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Foreword

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

Introduction

Cellulose is a polymer produced by 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. [4] 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.

In industrial productions, cellulose nanomaterials can be manufactured by conversion of wood pulp through chemical, biological or mechanical processes. In the case of bacterium-based cellulose nanomaterials, they are produced directly by bacteria and can be further acid-hydrolysed to smaller dimensions. Besides trees and bacteria, algae is another potential sources of cellulose nanomaterials for industrial applications. Due to their renewable nature and unique properties, 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.

In the current stage of development, several terms to describe cellulose nanomaterials coexist and have created confusion among users. Rather than delaying standards development until knowledge accumulated with market maturity is available, we have an opportunity to define a standard vocabulary for cellulose nanomaterials as they enter the market place. 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 — Standard terms and their definition for cellulose nanomaterial

1 Scope

This document defines terms and definitions for different types of cellulose nanomaterials including secondary components found in cellulose nanomaterials due to their manufacturing processes. The document also gives information on cellulose micromaterials in Annex A.

Where necessary, terms from the ISO/IEC 80004 vocabulary 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

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

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

— IEC Electropedia: available at http://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 predominately 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]

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 structure

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

3.2 Prerequiste non-nanotechnology terms related to cellulose nanomaterials

3.2.1
crystalline
solid structure where its ions, molecules, or atoms are in an ordered, three-dimensional arrangement

3.2.2
amorphous
solid structure where its ions, molecules, or atoms are oriented randomly, lacking any order

3.2.3
paracrystalline
structure in the intermediate state between crystalline and amorphous, having short and medium range ordered lattice structure and lacking long range order in at least one direction

3.2.4
cellulose
linear polymeric chains of β (1→4) linked D-glucopyranose units

3.2.5
elementary fibril
structure, originating from a single terminal enzyme complex, having a configuration of cellulose chains specific to each cellulose-producing plant, animal, algal and bacterial species

3.2.6
hemicellulose
non-cellulose polysaccharides 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 branched polymers.

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

3.3 Terms specific to cellulose nanomaterials

3.3.1
cellulose nanomaterial
CNM
material composed predominantly of *cellulose* (3.2.4), 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: The terms nanocellulose (NC) and cellulosic nanomaterial (CNM) are alternative terms for cellulose nanomaterial (CNM).

Note 2 to entry: Some cellulose nanomaterials can be composed of chemically modified cellulose.

Note 3 to entry: This generic 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* (3.2.4)

3.3.4
cellulose nanofibre
nanofibre (3.1.6) composed predominantly of *cellulose* (3.2.4)

3.3.5
cellulose nanocrystal
CNC
nanocrystal (3.1.7) predominantly composed of *cellulose* (3.2.4) with at least one *elementary fibril* (3.2.5), containing predominantly *crystalline* (3.2.1) and *paracrystalline* (3.2.3) regions, with aspect ratio of usually less than 50 but usually greater than 5, not exhibiting longitudinal splits, inter-particle entanglement, or network-like structures

Note 1 to entry: The dimensions are typically 3-50 nm in cross-section and 100 nm to several µm in length depending on the source of the cellulose nanocrystal.

Note 2 to entry: The aspect ratio refers to the ratio of the longest to the shortest dimension.

Note 3 to entry: Historically cellulose nanocrystals have been called nanocrystalline cellulose (NCC), whiskers such as cellulose nanowhiskers (CNW), and microfibrils such as cellulose microfibrils; 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.

3.3.6
cellulose nanofibril
CNF
cellulose (3.2.4) *nanofibre* (3.1.6) composed of at least one *elementary fibril* (3.2.5), containing *crystalline* (3.2.1), *paracrystalline* (3.2.3) and *amorphous* (3.2.2) regions, with aspect ratio usually greater than 10, which may contain longitudinal splits, entanglement between particles, or network-like structures

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

Note 2 to entry: The aspect ratio refers to the ratio of the longest to the shortest dimensions.

Note 3 to entry: The terms nanofibrillated cellulose (NFC), nanofibrillar cellulose (NFC), microfibrillated cellulose (MFC), microfibrillar cellulose (MFC), cellulose microfibril (CMF) and cellulose nanofibre (CNF) have been used to describe cellulose nanofibrils produced by mechanical treatment of plant materials often combined with chemical or enzymatic pre-treatment steps.

Note 4 to entry: Cellulose nanofibrils produced from plant sources by mechanical processes usually contain *hemicellulose* (3.2.6), and in some cases lignin.

Note 5 to entry: Some cellulose nanofibrils might have functional groups on their surface as a result of the manufacturing process.

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

Annex A
(informative)

Cellulose micromaterials

A cellulose microcrystal (CMC) is a cellulose object composed primarily of cellulose with a degree of polymerization typically less than 400. Less than 10% of the cellulose microcrystals in a production batch have diameters of less than 5 µm and aspect ratio of usually less than 2. The crystalline structure of cellulose microcrystal is composed of predominantly crystalline and paracrystalline regions.

CMCs may be manufactured by partially depolymerizing high purity cellulose such as α-cellulose. Alternative names for cellulose microcrystals include microcrystalline cellulose (MCC) or cellulosic microcrystals. The use of the abbreviation CMC in this context is not to be confused with its use for either 'carboxymethyl cellulose' or 'carboxymethylated cellulose' or 'critical micelle concentration'.