IEC TS 62565-5-2

Edition 1.0 2022-04

TECHNICAL SPECIFICATION

**Nanomanufacturing – Material specifications –
Part 5-2: Nano-enabled electrodes of electrochemical capacitors – Blank detail specification**

IEC TS 62565-5-2:2022-04(en)

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 07.120

ISBN 978-2-8322-1099-1

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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NANOMANUFACTURING – MATERIAL SPECIFICATIONS –

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FOREWORD

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IEC TS 62565-5-2 has been prepared by IEC technical committee 113: Nanotechnology for electrotechnical products and systems. It is a Technical Specification.

The text of this Technical Specification is based on the following documents:

Draft	Report on voting
113/628/DTS	113/643/RVDTS

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Technical Specification is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

A list of all parts in the IEC 62565 series, published under the general title *Nanomanufacturing – Material specifications*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

INTRODUCTION

This Technical Specification specifies how to report the various characteristics of electrodes for industrial use in electrotechnical products, and how to incorporate these into a bilateral detail specification between vendor and user.

Electrochemical capacitors are widely used in the fields of electric vehicles, high speed trains, aircraft, photovoltaic, wind power and electronics, due to their ultra-fast charge/discharge capability, long cycle life, wide working temperature range, high security reliability and low maintenance cost [1][1]. In the manufacture process of electrochemical capacitor, the electrode is a bridge between raw material and device. Therefore, the performance of the electrode is very critical in the whole electrochemical capacitor industry chain because the properties of electrodes not only reflect the performance of upstream raw material but also determine the performance of electrochemical capacitor [2][3][4][5][6][7][8][9].

For the purposes of development and commercialization of raw nanomaterials for electrodes and the electrochemical capacitor and assembly produced therefrom, the product characteristics and characterization methods need to be specified in a standardized way. This blank detail specification will benefit different stakeholders as follows: for material suppliers, it provides necessary feedback from the manufacturers to guide the design and production of raw materials; for the end-product manufacturers, it provides a toolbox for evaluating product quality so as to manage and improve process control, yield of products; for commercialization and trade, it provides a guidance on referred test methods for electrode classification; in addition, it will strengthen the links between material manufacture and down-stream user.

In this blank detail specification, the key chemical, physical, structural and electrochemical characteristics that will significantly influence the performance of electrochemical capacitors and their measurement methods are listed. These characteristics and characterization methods are not limited only to nano-enabled electrodes but also can be reference for other electrodes which are constructed by coating electrode materials on a current collector.

[1] Numbers in square brackets refer to the Bibliography.

NANOMANUFACTURING – MATERIAL SPECIFICATIONS –

Part 5-2: Nano-enabled electrodes of electrochemical capacitor – Blank detail specification

1 Scope

This part of IEC 62565, which is a Technical Specification, establishes a blank detail specification that lists the relevant key control characteristics (KCC) including chemical, physical, structural, and electrochemical characteristics of nano-enabled electrode for electrochemical capacitors. Electrodes of both electric double layer capacitors and pseudo capacitors with nano/ nanostructured materials such as nanoporous activated carbon, graphene, carbon nanotube, carbon black, carbon aerogel, carbon nanomaterial coating collector, etc., are included. For other electrodes, this document can be used for reference.

In addition, this document enables the customer to specify requirements in a standardized manner and to verify through standardized methods that the nano-enabled electrode of the electrochemical capacitors meets the required properties.

Numeric values to be specified for the characteristics in this document are intentionally left blank and are determined by agreement between customer and electrochemical capacitor supplier. Properties and characteristics deemed by the customer or supplier as not relevant to a specific application are classified as "not applicable" or "not specified".

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC TS 62607-4-2, *Nanomanufacturing – Key control characteristics – Part 4-2: Nano-enabled electrical energy storage – Physical characterization of cathode nanomaterials, density measurement*

IEC TS 62607-4-3, *Nanomanufacturing – Key control characteristics – Part 4-3: Nano-enabled electrical energy storage – Contact and coating resistivity measurements for nanomaterials*

IEC TS 62607-4-8, *Nanomanufacturing – Key control characteristics – Part 4-8: Nano-enabled electrical energy storage – Determination of water content in electrode nanomaterials, Karl Fischer method*

IEC TS 62607-6-20, *Nanomanufacturing – Key control characteristics – Part 6-20: Graphene-based material – Metallic impurity content: ICP-MS* [2]

ISO 9277, *Determination of the specific surface area of solids by gas adsorption – BET method*

ISO 15901-2, *Pore size distribution and porosity of solid materials by mercury porosimetry and gas adsorption – Part 2: Analysis of nanopores by gas adsorption*

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[2] Under preparation. Stage at the time of publication: IEC DTS 62607-6-20:2021.

ISO 25178 (all parts), *Geometrical product specifications (GPS) – Surface texture: Areal*

3 Terms and definitions

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

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

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

3.1 General terms

3.1.1
nanomaterial
material with any external dimension in the nanoscale or having internal structure or surface structure in the nanoscale

[SOURCE: ISO/TS 80004-1:2015, 2.4, modified – The two notes have been removed.]

3.1.2
nanostructured material
material having internal nanostructure or surface nanostructure

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

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

3.1.3
nano-enabled device
device in which the material elements or assembly of such elements exhibit performance or function only possible with nanotechnology

Note 1 to entry: The material element is a nanomaterial.

Note 2 to entry: The performance or function exhibited is measurable and significant for the application of the nano-enabled device.

Note 3 to entry: Applications of nano-enabled devices can include, but are not limited to, energy storage devices (capacitors, materials for lithium ion battery, fuel cell membrane, etc.), photovoltaic, organic electronics, and electro-optical devices.

[SOURCE: IEC 80004-9:2017, 3.1.5, modified – Notes 1 and 2 have been modified.]

3.1.4
key control characteristic
KCC
key performance indicator
material property or intermediate product characteristic which can affect safety or compliance with regulations, fit, function, performance, quality, reliability or subsequent processing of the final product

Note 1 to entry: The measurement of a key control characteristic is described in a standardized measurement procedure with known accuracy and precision.

Note 2 to entry: It is possible to define more than one measurement method for a key control characteristic if the correlation of the results is well-defined and known.

3.1.5
blank detail specification
BDS
structured generic specification of the set of key control characteristics which are needed to describe a specific nano-enabled product without assigning specific values and/or attributes

Note 1 to entry: The templates defined in a blank detail specification list the key control characteristics for the nano-enabled material or product without assigning specific values to it.

Note 2 to entry: Examples of nano-enabled products are: nanomaterials, nanocomposites and nano-subassemblies.

Note 3 to entry: Blank detail specifications are intended to be used by industrial users to prepare their detail specifications used in bilateral procurement contracts. A blank detail specification facilitates the comparison and benchmarking of different materials. Furthermore, a standardized format makes procurement more efficient and more error robust.

3.2 Terms related to capacitors

3.2.1
electrochemical capacitor
supercapacitor
device that stores electrical energy using a double layer in an electrochemical cell

Note 1 to entry: The electrochemical capacitor is not to be confused with electrolytic capacitors.

[SOURCE: IEC 60050-114:2014, 114-03-03]

3.2.2
electrode
conductive part in electric contact with a medium of lower conductivity and intended to perform one or more of the functions of emitting charge carriers to or receiving charge carriers from that medium or to establish an electric field in that medium

[SOURCE: IEC 60050-151:2001, 151-13-01]

3.2.3
electrode type
classification of the electrode of an electrochemical capacitor according to the charge-storage mechanism

Note 1 to entry: There are two electrochemical capacitor types: electric double layer capacitor and pseudo capacitor.

3.2.4
electric double layer capacitor
EDLC
device for electrostatic storage of electrical energy achieved by separation of charge in a double layer

[SOURCE: ISO 18300:2016, 3.8]

3.2.5
pseudo capacitor
Faraday capacitor
device for storage of electrical energy achieved by rapid oxidation-reduction reaction near the surface of electrode

3.3 General product description and procurement information

3.3.1
active material
material that can be used to store energy by electrochemical double-layer or pseudo capacitance effect

Note 1 to entry: Typically, nonreactive carbon materials are electric double-layer capacitance active material, including activated carbon, pure carbon nanotube and pure graphene.

Note 2 to entry: Typically, carbon composites and carbons embedded with heteroatoms are pseudo capacitance active material.

3.3.2
additive
material added in small quantities to a liquid or granular material to produce some desired modification to its characteristics

[SOURCE: ISO 6707-1:2020, 3.4.4.1]

3.3.3
nano-additive
additive that is nanomaterial or nano-structured material

3.3.4
graphene
graphene layer
single-layer graphene
monolayer graphene
1LG
single layer 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.

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) and few-layered graphene (FLG).

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]

3.3.5
nanofibre
nano-object with two similar external dimensions in the nanoscale 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.

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

3.3.6
nanotube
hollow nanofibre

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

3.3.7
carbon nanotube
nanotube composed of carbon