IEC TS 62565-5-1

Edition 1.0 2023-06

TECHNICAL SPECIFICATION

colour inside

Nanomanufacturing – Product specifications – Part 5-1: Nanoporous activated carbon – Blank detail specification: Electrochemical capacitors



IEC TS 62565-5-1:2023-06(en)



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Nanomanufacturing – Product specifications – Part 5-1: Nanoporous activated carbon – Blank detail specification: Electrochemical capacitors

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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NANOMANUFACTURING – PRODUCT SPECIFICATIONS –

Part 5-1: Nanoporous activated carbon – Blank detail specification: Electrochemical capacitors

FOREWORD

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IEC TS 62565-5-1 has been prepared by subcommittee 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
113/715/DTS	113/742/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/publications.

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

Future documents in this series will carry the new general title as cited above. Titles of existing documents in this series will be updated at the time of the next edition.

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- withdrawn,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.

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INTRODUCTION

This document specifies how to report the various characteristics of nanoporous activated carbon for electrochemical capacitors, 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, airplanes, photovoltaics, wind power and electronics, due to their ultra-fast charge and discharge capability, long cycle life, wide working temperature range, high security reliability and low maintenance cost [1] [1]. Nanoporous activated carbon is the active material in electrochemical capacitors [2], [3], [4] (Figure 1), and is one of the most critical factors that determine the electrochemical performance of a device.

Both precursor and process will affect the chemical, physical and structural characteristics of nanoporous activated carbon remarkably. The precursor of nanoporous activated carbon can be biomass, pitch and resin. The production process can be gas activation using diluted oxygen gas, steam, CO_2, etc., or chemical activation using H_3PO_4, $ZnCl_2$, KOH, etc. The chemical, physical and structural key control characteristics (KCCs) will significantly affect the electrochemical performance of nanoporous activated carbon. For instance, the metallic impurities will affect the self-discharging and endurance in cycling, the pore size distribution will affect the specific capacitance and the DC resistance. However, not all relationships between the chemical, physical, structure and application properties of active materials are clear so far. In the commercial market, the KCCs will be good indicators to choose an appropriate nanoporous activated carbon. Therefore, it is important to report KCCs, including electrochemical characteristics.

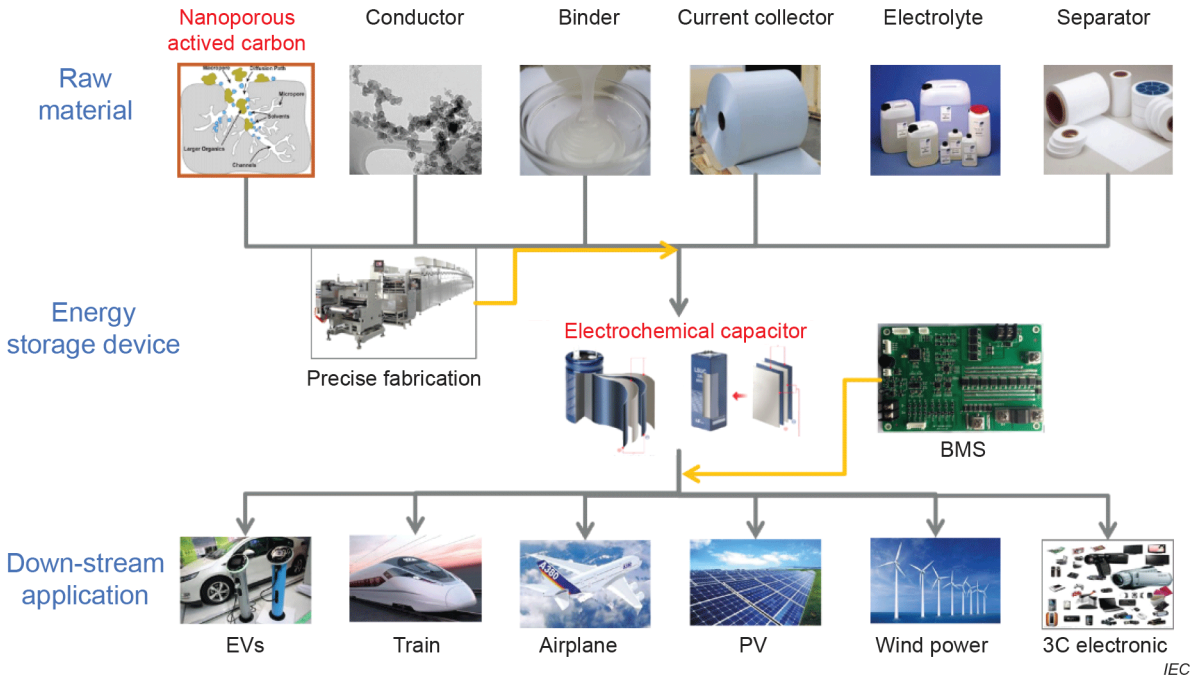
For nanoporous activated carbon manufacturers, the accurate characterization is critical for product optimization, finalization and quality control. For electrochemical capacitor manufacturers, who use the nanoporous activated carbon, before the large-scale production of electrochemical capacitors, the correct and accurate characterization of KCCs can be good indicators for choosing the appropriate raw materials and achieving quality assurance

To permit common processing equipment and common unit processes with predictable and reproducible results to be used in different fabrication lines, it is important for nanoporous activated carbon characteristics to be described and assessed in a proper manner and to standardize the methods for quality control of the manufacturing processes.

In this document, the key chemical, physical, structural and electrochemical characteristics that will significantly influence the performance of electrochemical capacitors are listed. This document also provides information about measurement methods and existing standards concerning the correct determination of KCCs.

---

1 Numbers in square brackets refer to the Bibliography.



Key

BMS battery management system

EVs electrical vehicles

PV photovoltaic power

3C computer, communication and consumer electronics

Figure 1 – Industrial chain of electrochemical capacitor

NANOMANUFACTURING – PRODUCT SPECIFICATIONS –

Part 5-1: Nanoporous activated carbon – Blank detail specification: Electrochemical capacitors

1 Scope

This part of IEC 62565, which is a Technical Specification, establishes a blank detail specification (BDS) for

- nanoporous activated carbon

used for

- electrochemical capacitors

Numeric values for the key control characteristics are left blank as they will be specified between customer and supplier in the detail specification (DS). In the DS key control characteristics can be added or removed if agreed between customer and supplier

2 Normative references

There are no normative references in this document.

3 Terms, definitions and abbreviated terms

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
nanomanufacturing
intentional synthesis, generation or control of nanomaterials, or fabrication step in the nanoscale, for commercial purposes

[SOURCE: ISO/TS 80004-1:2015, 2.11]

3.1.2
key control characteristic
KCC
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.

3.1.3
product specification
structured document which describes all characteristics of a product known to be relevant for applications of that product

3.1.4
blank detail specification
BDS
structured generic specification providing a comprehensive 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: Examples of nano-enabled products are: nanomaterials, nanocomposites and nano-subassemblies.

Note 2 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.

3.1.5
detail specification
DS
specification based on a blank detail specification with assigned values and attributes

Note 1 to entry: The properties listed in the detail specification are usually a subset of the key control characteristics listed in the relevant blank detail specification or sectional blank detail specification. The industrial partners define only those properties which are required for the intended application.

Note 2 to entry: Detail specifications are defined by the industrial partners. SDOs will be involved only if there is a general need for a detail specification in an industrial sector.

Note 3 to entry: The industrial partners may define additional key control characteristics if they are not listed in the blank detail specification or sectional blank detail specification.

3.1.6
measurand
quantity intended to be measured

Note 1 to entry: If the quantity is a key control characteristic, the measurement is an essential part of the quality management system.

3.1.7
measurement method
process of experimentally obtaining one or more values that can reasonably be attributed to a quantity

Note 1 to entry: If the quantity is a key control characteristic, the measurement is an essential part of the quality management system.

3.1.8
measurement principle
phenomenon serving as a basis of a measurement

EXAMPLE 1: Thermoelectric effect applied to the measurement of temperature.

EXAMPLE 2: Energy absorption applied to the measurement of amount-of-substance concentration.

EXAMPLE 3: Hall effect applied to the measurement of magnetic flux density.

Note 1 to entry: The phenomenon can be of a physical, chemical, or biological nature.

[SOURCE: IEC 60050-112:2010, 112-04-03]

3.1.9
measurement procedure
detailed description of a measurement according to one or more measurement principles and to a given measurement method, based on a measurement model, and including any calculation to obtain a measurement result

Note 1 to entry: A measurement procedure is usually documented in sufficient detail to enable an operator to perform a measurement.

Note 2 to entry: A measurement procedure can include a statement concerning a target measurement uncertainty.

Note 3 to entry: A measurement procedure is sometimes called a standard operating procedure, abbreviated SOP.

[SOURCE: ISO/IEC Guide 99:2007, 2.6]

3.1.10
measurement result
set of quantity values being attributed to a measurand together with any other available relevant information

Note 1 to entry: A measurement result is generally expressed as a single measured quantity value and a measurement uncertainty. If the measurement uncertainty is considered to be negligible for some purpose, the measurement result may be expressed as a single measured quantity value. In many fields, this is the common way of expressing a measurement result.

[SOURCE: ISO/IEC Guide 99:2007, 2.9, modified – Notes 1 and 3 to entry have been deleted.]

3.1.11
measurement accuracy
closeness of agreement between a measured quantity value and a true quantity value of a measurand

Note 1 to entry: The concept "measurement accuracy" is not a quantity and is not given a numerical quantity value. A measurement is said to be more accurate when it offers a smaller measurement error.

[SOURCE: ISO/IEC Guide 99, 2.13, modified – Note 2 and 3 to entry have been deleted.]

3.1.12
measurement standard
standardized measurement procedure
normative document established by consensus and approved by a recognized body, that provides a measurement procedure, for common and repeated use, aimed at the achievement of the optimum degree of order in a given context

Note 1 to entry: Standards are in general based on the consolidated results of science, technology and experience, and aimed at the promotion of optimum community benefits.

3.1.13
good practice guide
GPG
informal document which is not necessarily peer reviewed but can be used as a working document to establish a measurement procedure

Note 1 to entry: A GPG serves as the first document based on initial scientific research which is intended to be the first step toward future standardization.

3.1.14
standard maturity level
SML
measure for estimating the maturity of a measurement procedure based on the consensus achieved in the stakeholder community

Note 1 to entry: SML 1 – No documented measurement procedure available.

Note 2 to entry: SML 2 – Good practice guide publicly available based on a reasonable consensus achieved in the stakeholder community, e.g. an industrial or academic consortium.

Note 3 to entry: SML 3 – IEC or ISO standard or Technical Specification available which can be applied with modification and adaptation to the intended application and use case of the BDS scope.

Note 4 to entry: SML 4 – IEC or ISO standard or Technical Specification available for the exact intended application and use case of the BDS.

3.1.15
use case
specification of a generalized field of application, possibly entailing the following information about the system: one or several scenarios; the functional range; the desired behaviour; and the system boundaries

Note 1 to entry: The use case description typically does not include a detailed list of all relevant scenarios for this use case. Instead, a more abstract description of these scenarios is used.

[SOURCE: IEC TS 62565-1:2023, 3.18.]

3.1.16
procurement information
information other than key control characteristics needed for the procurement process.

3.2 Terms related to the nanoporous activated carbon

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
active material
material which electrostatically adsorbs and desorbs the ions at the electrode–electrolyte interface to store electric energy when the cell charges and discharges

3.2.3
nanopore
cavity with at least one dimension in the nanoscale, which may contain a gas or liquid

Note 1 to entry: The shape and content of the cavity can vary. The concept of nanopore overlaps with micropore (pore with width about 2 nm or less), mesopore (pore with width between approximately 2 nm and 50 nm), and macropore (pore with width greater than about 50 nm). See ISO 15901-3:2007.

Note 2 to entry: When nanopores are appropriately interconnected they may allow for transport through the material (permeability).

[SOURCE: ISO/TS 80004-4:2011, 2.13]

3.2.4
nanoporous material
solid material with nanopores

Note 1 to entry: The solid may be either amorphous, crystalline, or a mixture of both.

Note 2 to entry: The definitions of solid nanofoam (where most of the volume is occupied by pores) and nanoporous material (also materials with a small fraction of pores covered) are overlapping.

[SOURCE: ISO/TS 80004-4:2011, 3.4]

3.2.5
activated charcoal
activated carbon
carbon, usually in the form of granules, treated to enhance its surface area and consequent ability to adsorb and desorb the ions through a highly developed pore structure

3.2.6
nanoporous activated carbon
activated carbon with nanopores

Note 1 to entry: The performance of such activated carbon application mainly depends on its nanoporous structure.

3.3 Chemical key control characteristics

3.3.1
water content
ratio, expressed in percent, between the mass of water contained in the material as received and the corresponding dry residue of the material

[SOURCE: ISO 21268-2:2019, 3.6, modified – Note 1 to entry has been deleted.]

3.3.2
ash content
percent by mass of carbon-free residue on combustion and pyrolysis

[SOURCE: ISO 1998-2:1998, 2.10.120]

3.3.3
metallic impurity
magnetic element, such as Fe, Co, Ni, present but not intentionally added to a material, and the minimum content of which is not controlled

3.3.4
elemental content
content of element, such as C, H, N, S, O, P, Si, within moisture free material, expressed in percent of mass

3.3.5
anion impurity
anion, such as Cl^-, SO_4^{2-}, NO_3^-, present but not intentionally added to a material, and the minimum content of which is not controlled

3.3.6
functional group
atom, or a group of atoms that has similar chemical properties whenever it occurs in different compounds, which defines the characteristic physical and chemical properties of families of organic compounds

[SOURCE: IEC TS 62607-6-13:2020, 3.1.2.2]

3.3.7
oxygen functional group
functional group containing oxygen atom

[SOURCE: IEC TS 62607-6-13:2020, 3.1.2.3]

3.4 Physical key control characteristic

3.4.1
particle size distribution
cumulative distribution of particle concentration as a function of particle size

[SOURCE: ISO 14644-1:2015, 3.2.4]

3.4.2
tap density
density of a powder in a container that has been tapped under specified conditions

[SOURCE: ISO 12749-3:2015, 3.4.4]

3.4.3
apparent density
loose bulk density
dry mass per unit volume of a powder obtained by free pouring under specified conditions

[SOURCE: ISO/TS 23362:2021, 3.1.4]

3.4.4
volume resistivity
ρ_V
measured volume resistance calculated to apply to a cube of unit side

Note 1 to entry: It is expressed in ohm metres (Ω·m).

[SOURCE: ISO 14309:2019, 3.3]

3.4.5
pH value
measure of the concentration of acidity or alkalinity of a material in an aqueous solution

[SOURCE: ISO 20976-1:2019, 3.15]

3.4.6
circularity
degree to which the projected area of the particle is similar to a circle, based on its perimeter

3.5 Structural key control characteristics

3.5.1
specific surface area
absolute surface area of the sample divided by sample mass

[SOURCE: ISO 9277:2022, 3.11]

3.5.2
pore volume
volume of open pores unless otherwise stated

[SOURCE: ISO 15901-1:2016, 3.14]

3.5.3
pore size distribution
percentage by numbers or by volume of each classified pore size which exists in a material

[SOURCE: ISO 3252:2019, 3.3.47]

3.5.4
crystal structure
arrangement of a regular and repeating internal unit of atoms in three dimensions in which the atoms are set in space in a fixed relation to each other

Note 1 to entry: For carbon material, interplanar spacing and crystallite size are important parameters to describe the crystal structure.

[SOURCE: ISO/TS 11937:2012, 3.4, modified – Note 1 to entry has been added.]

3.5.5
interplanar spacing
d_{hkl}
perpendicular distance between consecutive planes of the crystallographic plane set ($h\ k\ l$)

Note 1 to entry: For carbon material, especially amorphous carbon, interplanar spacing d_{002} of crystallographic plane set (002) is used to describe the distance between two adjacent graphene layers.

[SOURCE: ISO 25498:2018, 3.6, modified – Note 1 to entry has been added.]

3.5.6
crystallite size
dimensions of a single coherent crystalline region

Note 1 to entry: The mean size of crystal thickness L_{c} and crystal diameter L_{a} are often used to describe the crystallite size of carbon material.

3.6 Electrochemical key control characteristics

3.6.1
capacitance
ability of a capacitor to store electrical charge

Note 1 to entry: Unit: farad (F).

[SOURCE: IEC 62576:2018, 3.5, modified – Information on units has been moved to a Note 1 to entry.]

3.6.2
internal resistance
combined resistance of constituent material specific resistance and inside connection resistance of a capacitor

Note 1 to entry: Unit: ohm (Ω).

[SOURCE: IEC 62576:2018, 3.15, modified – Information on units has been moved to a Note 1 to entry.]

3.6.3
specific capacitance
capacitance of capacitor divided by the mass or volume of active material mass

Note 1 to entry: Unit: farad per gram (F/g) or farad per cubic centimetre (F/cm^3).

3.6.4
leakage current
value of the current that flows through a capacitor after a charge for a fixed period of time

Note 1 to entry: Unit: ampere (A).

[SOURCE: IEC 62391-1:2022, 3.12, modified – Note 2 to entry has been deleted.]

3.6.5
voltage maintenance rate
ratio of voltage maintenance
ratio of the voltage at the open-ended terminals to the charge voltage after a specified time period subsequent to the charging of a capacitor

[SOURCE: IEC 62576:2018, 3.25]

3.6.6
endurance in cycling
number of charge and discharge cycles when the measured capacitance or internal resistance value reaches a specified degree of its initial value under a certain temperature and a certain rate of charge current

3.6.7
temperature endurance
ratio of the capacitance or internal resistance to its initial value after a specified charging time at constant voltage charge under a certain temperature

3.7 Measurement methods

3.7.1
constant current discharge
CCD
discharge during which the electric current is maintained at a constant value regardless of the battery voltage or temperature

3.7.2
constant current charge
CCC
charge during which the electric current is maintained at a constant value regardless of the battery voltage or temperature

[SOURCE: IEC 60050-482:2004, 482-05-38]

3.7.3
constant voltage charge
CVC
charge during which the voltage is maintained at a constant value regardless of charge current or temperature

[SOURCE: IEC 60050-482:2004, 482-05-49]

3.8 Symbols and abbreviated terms

ICP	inductively coupled plasma
MS	mass spectrometry
OES	optical emission spectroscopy
XRF	X-ray fluorescence
AAS	atomic absorption spectrometry
XPS	X-ray photoelectron spectroscopy
FT-IR	Fourier transform infrared spectroscopy
SEM	scanning electron microscopy
XRD	X-ray diffraction
GCD	galvanostatic charge and discharge
GC	galvanostatic charge
CV	constant voltage
S	surface area
C	circularity
X_{Fmax}	maximum Feret diameter
EDLC	electric double layer capacitor
IGD	infrared gas detector
TCD	thermal conductivity detector