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TECHNICAL SPECIFICATION

Nanomanufacturing – Product specification –
Part 5-3: Nanoenabled energy storage – Blank detail specification: silicon nanosized materials for the negative electrode of lithium-ion batteries

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IEC TS 62565-5-3 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
113/842/DTS	113/879/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 specification*, 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- withdrawn, or
- revised.

INTRODUCTION

This document specifies how to report various characteristics of silicon nanosized materials for the negative electrode for industrial use in electrotechnical products, and how to incorporate these characteristics into a bilateral detail specification between vendor and user.

Lithium-ion batteries have been widely employed in the fields of portable devices, power tools, electric vehicles and energy storage systems. Graphite, silicon-carbon composite, silicon monoxide, lithium titanate, soft carbon, hard carbon, metal oxides and other materials can be used as negative active materials for lithium-ion batteries. Currently, the most widely commercialized negative active material is graphite, which has many advantages such as low lithiation potential, high conductivity, low volume expansion and stable cycle performance. However, the capacity of graphite is only 372 mAh/g and unable to meet the increasing demand for high energy density. Therefore, it is essential to develop new negative active materials with high capacity.

The theoretical capacity of silicon negative active material is 4 200 mAh/g, which is ten times higher than that of graphite. However, it has disadvantages of huge volume expansion and low electronic conductivity, resulting in poor cycle performance. Massive efforts have been devoted to solve these problems, including:

a) controlling the size of Si particles (e.g. using silicon nanosized material);
b) combining Si with carbon or other materials since carbon can form a conductive network and buffer the expansion of Si;
c) enhancing the stability of the interface between Si and electrolyte by using new binders or electrolyte additives.

Silicon nanosized materials for the negative electrode have advantages of high capacity, high safety and abundant raw materials. Different kinds of methods have been explored to prepare silicon nanosized materials for the negative electrode in universities, institutes and industries. Silicon nanosized materials for the negative electrode with different morphology or structure can lead to distinct differences in physical and chemical performance. More effort and investment are needed in order to further understand the properties of silicon nanosized materials for the negative electrode.

The method of combining silicon nanosized material with carbon is regarded as one of the most effective ways to release the stress induced by the expansion upon lithiation/delithiation process, avoiding the fracture and pulverization of Si particles. Si-C negative active material has been commercialized for several years. Though the problem of expansion is partially resolved, it remains the key factor that prevents silicon from large-scale commercial applications. At the same time, the demand for silicon nanosized materials for the negative electrode is growing rapidly. Therefore, it is essential to standardize a blank detail specification of characterization techniques and measurement methods for the properties of silicon nanosized materials for the negative electrode.

In this document, the key physical, chemical, electrochemical and structural characteristics that will significantly influence the performance of silicon nanosized materials for the negative electrode are listed, as well as those corresponding measurement methods. Furthermore, characterization techniques and measurement methods for particular properties of silicon nanosized materials for the negative electrode which need to be standardized are summarized in a matrix form. The matrix can serve as a guide for developing necessary International Standards on characterization and measurements of silicon nanosized materials for the negative electrode and related silicon-based negative active materials.

NANOMANUFACTURING – PRODUCT SPECIFICATION –

Part 5-3: Nanoenabled energy storage – Blank detail specification: silicon nanosized materials for the negative electrode of lithium-ion batteries

1 Scope

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

- silicon nanosized materials

used for

- negative electrode of lithium-ion batteries.

This document is intended to be used for silicon nanosized materials for the negative electrode of lithium-ion batteries which have been widely employed in the fields of

– portable devices,

– power tools,

– electric vehicles, and

– energy storage system.

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

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 62607-4-2:2016, *Nanomanufacturing – Key control characteristics – Part 4-2: Nano-enabled electrical energy storage – Physical characterization of cathode nanomaterials, density measurement*

IEC TS 62607-4-7:2018, *Nanomanufacturing – Key control characteristics – Part 4-7: Nano-enabled electrical energy storage – Determination of magnetic impurities in anode nanomaterials, ICP-OES method*

IEC TS 62607-4-8:2020, *Nanomanufacturing – Key control characteristics – Part 4-8: Nano-enabled electrical energy storage – Determination of water content in electrode nanomaterials, Karl Fischer method*

IEC TS 62607-6-1:2020, *Nanomanufacturing – Key control characteristics – Part 6-1: Graphene-based material – Volume resistivity: four probe method*

ISO 3923-1:2018, *Metallic powders – Determination of apparent density – Part 1: Funnel method*

ISO 3953:2011, *Metallic powders – Determination of tap density*

ISO 9277:2022, *Determination of the specific surface area of solids by gas adsorption – BET method*

ISO 9516-1:2003, *Iron ores – Determination of various elements by X-ray fluorescence spectrometry – Part 1: Comprehensive procedure*

ISO/TS 10797:2012, *Nanotechnologies – Characterization of single-wall carbon nanotubes using transmission electron microscopy*

ISO 11357-5:2013, *Plastics – Differential scanning calorimetry (DSC) – Part 5: Determination of characteristic reaction-curve temperatures and times, enthalpy of reaction and degree of conversion*

ISO 12154:2014, *Determination of density by volumetric displacement – Skeleton density by gas pycnometry*

ISO 13320:2020, *Particle size analysis – Laser diffraction methods*

ISO 15202-3:2004, *Workplace air – Determination of metals and metalloids in airborne particulate matter by inductively coupled plasma atomic emission spectrometry – Part 3: Analysis*

ISO 15350:2000, *Steel and iron – Determination of total carbon and sulfur content – Infrared absorption method after combustion in an induction furnace (routine method)*

ISO 15632:2021, *Microbeam analysis – Selected instrumental performance parameters for the specification and checking of energy-dispersive X-ray spectrometers (EDS) for use with a scanning electron microscope (SEM) or an electron probe microanalyser (EPMA)*

ISO 15901-1:2016, *Evaluation of pore size distribution and porosity of solid materials by mercury porosimetry and gas adsorption – Part 1: Mercury porosimetry*

ISO 15901-2:2022, *Pore size distribution and porosity of solid materials by mercury porosimetry and gas adsorption – Part 2: Analysis of nanopores by gas adsorption*

ISO 17053:2005, *Steel and iron – Determination of oxygen – Infrared method after fusion under inert gas*

ISO 19396-1:2017, *Paints and varnishes – Determination of pH value – Part 1: pH electrodes with glass membrane*

ISO 19749:2021, *Nanotechnologies – Measurements of particle size and shape distributions by scanning electron microscopy*

ISO 20720:2018, *Microbeam analysis – Methods of specimen preparation for analysis of general powders using WDS and EDS*

ISO 22036:2024, *Environmental solid matrices – Determination of elements using inductively coupled plasma optical emission spectrometry (ICP-OES)*

EN 13925-2:2003, *Non-destructive testing – X-ray diffraction from polycrystalline and amorphous materials – Part 2: Procedures*