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Nanotechnologies — Silica nanomaterials — ~~Specification of~~ Characteristics and measurement methods for silica with ordered nanopore array (SONA)

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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~~The committee responsible for~~ This document ~~is~~was prepared by Technical Committee ISO/TC 229, *Nanotechnologies*.

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Introduction

Silica with ordered nanopore array (SONA) is expected to act as novel catalysts and adsorbents because of the presence of their uniform nanopores. In addition to ~~them~~SONA, recently developed synthetic strategies have created a huge number of compositional and morphological variations. Therefore, ~~it~~SONA is expected to be applied in various fields such as electronics, optics~~,~~ and materials. They ~~have stimulated various applications such as electronic, photonic, and materials applications. Also, they~~also have potential uses as electrodes for fuel cells and hydrogen-storage materials, all of which are owing to the presence of periodic nanopore and the physical properties of inorganic frameworks.

SONA as described in the previous reports[1~~-]~~[5] has an amorphous structure like silica-gel and exhibits a honeycomb (hexagonal), 3D (cubic) and wormhole (gyroid) pore structure (see Annex A) with ordered cylindrical channels from 2 nm to 50 nm in diameter. The pores are constructed with thin silica walls which are connected to form the regular pore arrangements. The delicate structures of silica walls and their connected structures are influenced by their preparation, aging and storage conditions. The global SONA market is anticipated to witness significant growth on account of a wide range of existing and potential applications of the product in electronics, biomedical, drug delivery~~,~~ and optical fields. A market survey shows extensive use of SONA in the chemical industry as a catalyst support for synthesis of various chemicals[6].

SONA have a variety of industrial applications as catalysts, adsorbents, molecular sieve, where their properties and use cases highly depend on their production processes that affect their nanopore arrangements. They do not have long-range SiO_2 ordering confirmed by powdered X-ray diffraction, showing XRD peaks in low angle region (see Annex A). Having the ability to characterize these materials helps developers adapt to new research frontiers such as bulky organometallic or inorganic complexes, biosensors from embedded enzymes on nanostructured silica~~[~~[7]~~-]~~[8]~~]~~ to application in energy-efficient desiccation. Standardization of SONA can unify different types of SONA test reports in industry. This allows users to compare or select most suitable and qualified SONA for their applications.

~~Technical Specification~~

Nanotechnologies — Silica nanomaterials — Characteristics and measurement methods for silica with ordered nanopore array (SONA)

1 Scope

This document specifies the characteristics of ~~silica~~ samples of silica with ordered nanopore array (SONA) to be measured in powder form and ~~specifies~~the industrially available measurement methods used to determine said characteristics. ~~It~~ This document provides a sound base for the research, development~~,~~ and commercialization of SONA for various applications.

~~Nanotechnologies – Silica nanomaterials - Specification of characteristics and measurement methods for silica with ordered nanopore array (SONA)~~

~~1 1 Scope~~

~~This document specifies characteristics to be measured and their measurement methods of silica with ordered nanopore array (SONA) in powder form.~~

This document excludes silica-gel, fumed silica and chemically modified SONA.

NOTE ~~1:~~ The pore size of SONA ranges usually from one ~~nanometer~~nanometre to several tens of ~~nanometers~~nanometres.

2 ~~2~~ Normative references

~~ISO/TS 80004-2 Nanotechnologies – Vocabulary – Part 2: Nano-objects~~

~~ISO/TS 80004-4 Nanotechnologies – Vocabulary – Part 4: Nanostructured materials~~

~~ISO/TS 80004-6 Nanotechnologies – Vocabulary – Part 6: Nano-object characterization~~

There are no normative references in this document.~~3~~

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
area equivalent diameter
diameter of a circle having the same area as the projected image of the particle

Note 1 to entry: It is also known as the Heywood diameter or as the equivalent circular diameter.

[SOURCE: ISO 13322-1:2014~~(en),~~ 3.1.1]

3.2
Feret diameter
x_F
distance between two parallel tangents on opposite sides of the image of a particle

Note 1 to entry: Maximum diameter x_{Fmax} corresponding to the "length" of the particle and minimum diameter x_{Fmin} corresponding to the "breadth" of the particle.

[SOURCE: ISO 13322~~-2:2004, 3.1.6~~-1:2014, 3.1.6, modified — Note 1 to entry has been added.]

3.3
nanopore
cavity with at least one dimension in the *nanoscale* (3.4), which ~~may~~can 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 (i.e. pore with width of about 2 nm or less), mesopore (i.e. pore with width between approximately 2 nm and 50 nm), and macropore (i.e. pore with width greater than about 50 nm).

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

[SOURCE; ISO~~/TS~~ 80004-~~4, 2.13]~~

1:2023, 3.4.3, modified — Notes 1 and 2 to entry have been added.]

3.4
nanoscale
size range from approximately 1 nm to 100 nm

Note 1 to entry: Properties that are not extrapolations from a larger size will typically, but not exclusively, be exhibited in this size range. For such properties, the size limits are considered approximate.

Note 2 to entry: The lower limit in this definition (approximately 1 nm) is introduced to avoid single and small groups of atoms from being designated as nano-objects or elements of nanostructures, which ~~might~~can be implied by the absence of a lower limit.

[SOURCE: ISO~~/TS~~ 80004-1:~~2010,~~2023, 3.1.1, modified — Notes 1 and 2~~.1]~~ to entry have been added.]

3.5
ordered nanopore array
nanopores (3.3) formed and arranged in a pattern according to the specified rule

Note 1 to entry: The ordered nanopore array can be fully or partially regular depending on the ~~*SONA*~~*silica with ordered nanopore array* (3.7) sample.

Note 2 to entry: See Annex A for the types of pore array.

3.6
particle size
~~dimension that is representative of the size of an individual particle~~

~~Note to entry: The particle size is usually expressed as Feret diameter or area equivalent diameter~~

~~[~~diameter of sediment particles

[SOURCE: ISO 772:~~2011(en), 6.37 modified, note to entry added.]~~2022, 8.41]

3.7
pore size
pore width, i.e~~.,~~. diameter of cylindrical pore or distance between opposite walls of slit~~.~~

[SOURCE: ~~ISO15901~~ISO 15901-2~~:~~:2022, 3.17]

3.8
pore size distribution
fraction by numbers or by volume of each classified *pore size* (3.7) which exists in a material

Note 1 to entry~~:~~: The pore size distribution is usually expressed by the full width at half maximum of the distribution main peak.

[SOURCE: ISO 3252:~~2019~~2023, 3.3.47, modified — "percentage" has been replaced with "fraction~~]~~" in the definition and Note 1 to entry has been added.]

3.9
silica with ordered nanopore array
SONA
amorphous silica containing internal structures in the form of *ordered nanopore array* (3.5)

4 ~~4~~ Abbreviated terms

~~AAS atomic absorption spectrometry~~

~~AFM atomic force microscopy~~

~~BET Brunauer–Emmett–Teller~~

~~BJH Barrett-Joyner-Halenda~~

~~DSC differential scanning calorimetry~~

~~EDX energy dispersive X-ray spectrometry~~

~~EPMA electron probe micro analyser~~

~~ICP inductively coupled plasma~~

~~IR infrared spectrometry~~

~~SEM scanning electron microscopy~~

~~Si-MAS-NMR silicon magic angle spinning-nuclear magnetic resonance~~

~~TEM transmission electron microscopy~~

~~TGA thermal gravimetric analysis~~

~~XRD X-ray diffraction~~

~~XRF X-ray fluorescence spectrometry~~

~~XPS X-ray photoelectron spectrometry~~

AAS atomic absorption spectrometry
AFM atomic force microscopy
BET Brunauer–Emmett–Teller
BJH Barrett-Joyner-Halenda
EDX energy dispersive X-ray spectrometry
EPMA electron probe micro analyser
ICP inductively coupled plasma
SEM scanning electron microscopy
TEM transmission electron microscopy

