INTERNATIONAL STANDARD

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Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for air-purification performance of semiconducting photocatalytic materials by test chamber method under indoor lighting environment —

Part 1: Removal of formaldehyde

Céramiques techniques — Méthode d'essai pour mesurer les performances des matériaux photocatalytiques semiconducteurs pour purifier l'air selon la méthode de la chambre d'essai dans un environnement d'éclairage intérieur —

Partie 1: Élimination du formaldéhyde

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Contents

Page

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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword — Supplementary information.

The committee responsible for this document is ISO/TC 206, *Fine ceramics*.

ISO 18560 consists of the following parts, under the general title *Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for air-purification performance of semiconducting photocatalytic materials by test chamber method under indoor lighting environment*:

— *Part 1: Removal of formaldehyde*

Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for air-purification performance of semiconducting photocatalytic materials by test chamber method under indoor lighting environment —

Part 1: Removal of formaldehyde

1 Scope

This part of ISO 18560 specifies a test method for the determination of the air-purification performance of materials that contain a indoor-light-active photocatalyst or have indoor-light-active photocatalytic films on the surface, usually made from semiconducting metal oxides, such as titanium dioxide or other ceramic materials, by continuous exposure of a test piece to the model air pollutant under illumination with indoor light. Formaldehyde (HCHO) is chosen because it is a typical indoor air pollutant that causes the so-called sick building syndrome. This part of ISO 18560 is intended to evaluate the photocatalytic performance for building materials, such as boards, wallpapers. This part of ISO 18560 does not apply to powder or granular photocatalytic materials.

This test method is usually applicable to indoor-light-active photocatalytic materials produced for air purification. This method is not suitable for the determination of other performance attribute of photocatalytic materials, i.e. decomposition of water contaminants, self-cleaning, antifogging and antibacterial actions. This test method is based on ISO 16000-23 and is adjusted for the measurement of indoor-light-active photocatalytic materials.

NOTE Another test method for the determination of air-purification performance of photocatalytic materials by using formaldehyde is described in ISO 22197-4. The test methods comprising of ISO 22197 are prepared for evaluation of material-based air-purification performance under irradiation of ultraviolet light, while this part of ISO 18560 is intended for providing a direct index to the improvement of indoor air quality by the indoor-light-active photocatalytic materials under the simulated conditions. Approximate correlation between the results by ISO 22197-4 and this part of ISO 18560 has been confirmed.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 6353-3, *Reagents for chemical analysis — Part 3: Specifications — Second series*

ISO 14605, *Fine ceramics (advanced ceramics, advanced technical ceramics) — Light source for testing semiconducting photocatalytic materials used under indoor lighting environment*

ISO 16000-3, *Indoor air — Part 3: Determination of formaldehyde and other carbonyl compounds — Active sampling method*

ISO 16000-6, *Indoor air — Part 6: Determination of volatile organic compounds in indoor and test chamber air by active sampling on Tenax TA® sorbent, thermal desorption and gas chromatography using MS/FID*

ISO 16000-9, *Indoor air — Part 9: Determination of the emission of volatile organic compounds from building products and furnishing — Emission test chamber method*

ISO 16000-11, *Indoor air — Part 11: Determination of the emission of volatile organic compounds from building products and furnishing — Sampling, storage of samples and preparation of test specimens*

3 Terms and definitions

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

3.1
photocatalyst
substance that performs one or more catalytic functions based on oxidation or reduction reactions under photoirradiation

Note 1 to entry: The functions include decomposition and removal of air and water contaminants, deodorization, antibacterial, self-cleaning and antifogging actions. A photocatalyst can also be used for light energy conversion.

3.2
indoor-light-active photocatalyst
photocatalyst (3.1) that functions under illumination with artificial light used for general lighting purposes

3.3
indoor lighting environment
illumination with artificial light source(s) used for general lighting purposes and excluding sunlight

3.4
indoor-light-active photocatalytic materials
materials in which or on which the *indoor-light-active photocatalyst* (3.2) is added by coating, impregnation, mixing, etc.

3.5
photocatalytic materials
materials in which or on which the *photocatalyst* (3.1) is added by coating, impregnation, mixing, etc.

3.6
zero-calibration gas
purified air that does not contain pollutants which affect the test and gas analysis

Note 1 to entry: The zero-calibration gas is supplied as a synthetic air in a gas cylinder. It can also be prepared from indoor air using a laboratory air purification system.

3.7
supply air spiked with formaldehyde
mixture of high purity air and formaldehyde of known concentration prepared from a standard gas or a *zero-calibration gas* (3.6), to be used for the performance test of a *photocatalytic material* (3.5)

3.8
air change rate
ratio of the volume of supply air admitted to the test chamber per hour and the free test chamber volume measured in identical units

3.9
air flow rate
air volume admitted to the test chamber per unit time

3.10
product loading factor
ratio of exposed surface area of the test specimen and the free test chamber volume

3.11
dark condition
test condition of no light illumination by the light source for testing and room lightings

3.12
equivalent ventilation rate per area
clean air ventilation rate that would be required to reduce the formaldehyde concentration by the same amount as produced per unit area of the *photocatalytic material* (3.5) when exposed to indoor light

3.13
guideline concentration
guideline indoor air concentration for formaldehyde as specified by the World Health Organization (WHO)

Note 1 to entry: The guideline indoor air concentration for formaldehyde specified by the WHO is 100 μg/m^3. Reference to national standards is possible if this is clearly highlighted in the test report and test certificate.

3.14
mass transfer coefficient
diffusion rate constant of the formaldehyde flux driven by the concentration difference between the test specimen and ambient air over its surface

Note 1 to entry: Mass transfer coefficient is expressed in meters per hour.

3.15
recovery
measured mass of formaldehyde in the air leaving the test chamber with no sample present conditioned over a given time period divided by the mass of formaldehyde added to the test chamber in the same time period

Note 1 to entry: The recovery is expressed as a percentage and provides information about the performance of the entire method.

3.16
sampling time
period of time during which air is sampled from the outlet of the test chamber using sampling tubes or other devices

3.17
supply air concentration
mass concentration of formaldehyde in air for supply to the test chamber

3.18
irradiation start
time of starting irradiation of indoor light to the specimen

3.19
elapsed time
time from *irradiation start* (3.18) to the start of air sampling

3.20
test chamber concentration
concentration of formaldehyde measured at the outlet of a test chamber, derived by dividing the mass of the formaldehyde sampled at the outlet of the chamber by the volume of sampled air

4 Symbols

$\rho_{in,\,t}$ concentration of formaldehyde at test chamber inlet at elapsed time t (micrograms per cubic metre)

$\rho_{out,\,t}$ test chamber concentration at elapsed time t (micrograms per cubic metre)

ρ_{gl} guideline concentration (micrograms per cubic metre)

k_a mass transfer coefficient determined using water vapour (metres per hour)

L product loading factor (square metres per cubic metre)

n air change rate (changes per hour)

q_a area specific air flow rate (cubic metres per square metre per hour)

q_c air flow rate of test chamber (cubic metres per hour)

q_{eq} equivalent ventilation rate (cubic metres per square metre per hour)

r removal rate (micrograms per square metre per hour)

r_{gl} removal rate when test chamber concentration is equal to guideline concentration (micrograms per square metre per hour)

t_e elapsed time (hours or days)

V air volume of test chamber (cubic metres)

A surface area of the test specimen exposed to illumination (square metres)

5 Principle

The test piece, placed in a test chamber, is activated by indoor light illumination, and adsorbs and oxidizes gas-phase formaldehyde to form carbon dioxide (CO_2) and other oxidation products. The air purification performance is determined by monitoring the reduction in formaldehyde concentration of the air leaving the test chamber.

The method uses a supply air spiked with formaldehyde at approximately the same concentration as the WHO guideline level for formaldehyde in indoor air (100 µg/m^3), see Reference [1]. Reference to national standards may be made if this is clearly stated in the test report and test certificates.

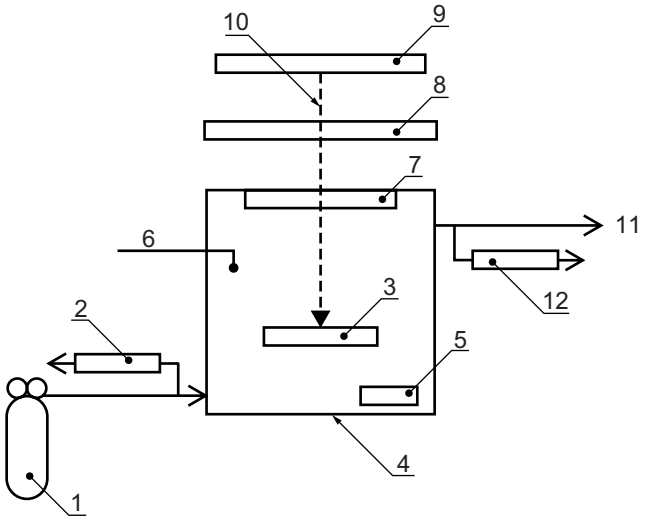
6 Apparatus

6.1 General

The apparatus necessary for measuring the removal performance of an indoor-light-active photocatalytic material in test consists of:

- test chamber;
- sealing material for test specimen;
- air purifier or other source of contamination-free air;
- supply air spiked with formaldehyde;
- temperature and humidity controls;
- air flow meter;
- light source;
- UV sharp cut-off filter;
- air sampling devices;
- analytical instruments.

See Figure 1.



Key

1 supply air spiked with formaldehyde
2 sampling device
3 test specimen
4 test chamber
5 device to circulate air and control of air velocity
6 temperature/humidity monitoring apparatus
7 glass window
8 UV sharp cut-off filter
9 light source
10 light irradiation
11 test chamber outlet
12 sampling device

Figure 1 — Schematic of the test system

6.2 Test chamber

A test chamber covered by this part of ISO 18560 shall comply with relevant specifications and requirements of ISO 16000-9 and have a glass window through which indoor-light irradiates a specimen. For low light-absorption over 380 nm wavelength, the window shall be constructed with silica glass or borosilicate glass. No air shall be allowed to circulate from the outlet back to the inlet.

6.3 Sealing material for test specimens

Aluminium foil or a tape covered with aluminium foil shall be used to cover the edges and the back of the test specimen.

6.4 Air purifier

Supply air before being spiked with formaldehyde shall be as clean as possible. In order to prevent a rise in background concentration, an air purifier shall be provided or clean cylinder air shall be used.

6.5 Supply air spiked with formaldehyde

Apply a standard gas (with known formaldehyde concentration) or a stable source like a formaldehyde solution as specified in ISO 6353-3, or paraformaldehyde, to generate air spiked with formaldehyde that can be supplied to the test chamber. Stability of formaldehyde concentration shall be monitored.

6.6 Temperature and humidity controls

The temperature shall be maintained either by installing the test chamber in a temperature controlled environment, such as a constant-temperature climate chamber, or by maintaining the required temperature in the chamber. Relative humidity shall be maintained in accordance with 7.2.1. Temperature and humidity controls of the supply air are described in ISO 16000-9.

6.7 Air flow meter

An air flow meter shall be installed at the inlet or the outlet of the test chamber to measure the air flow rate through the chamber.

6.8 Light source and UV sharp cut-off filter

The light source for indoor lighting environment is specified in ISO 14605. A halophosphate or triphosphor fluorescent lamp with a correlated colour temperature of between 3 800 K to 4 500 K shall be used. When a triphosphor fluorescent lamp is used for evaluating, the fluorescent lamp of the CIE 1974 general colour rendering index (Ra) defined by CIE 13.3 higher than 80 shall be selected. A UV sharp cut-off filter specified in ISO 14605 shall be used under UV cut-off condition. The test specimen shall be irradiated uniformly through the window by the light source. The light source that requires warming up shall be equipped with a shutter. The distance between the light source and the chamber shall be adjusted so that the illuminance on the test specimen surface is 1 000 lx ± 50 lx. The irradiance along the length of the test specimen shall also be constant within ± 5 %. The illuminance shall be measured with an illuminance meter which has been calibrated by a calibration laboratory. Reflection plate of luminaire and a shielding device of the reactor from external light are to show small or constant absorption in UV and indoor light. The reactor shall be shielded from external light if necessary.

6.9 Air sampling devices

The inlet and outlet air of the test chamber shall both be sampled.

If a duct or tube is used, it shall be as short as possible and maintained at the same air temperature as that in the test chamber. Such a duct or tube shall be made of a material with a very low sorption capacity, such as polytetrafluoroethylene.

The sum of sampling air flow rates shall be smaller than the air flow rate into the chamber. Sampling devices shall comply with the specifications of ISO 16000-3. When the air is sampled from the inlet, ensure the supply air flow rate remains constant.

A multiport sampling manifold may be used to provide flexibility for duplicate air sampling.

The exhaust from the test chamber should be ducted into a fume hood, ensuring that air spiked with formaldehyde and any chemicals emitted from the test material are isolated from the laboratory environment.

6.10 Device to circulate air and control of air velocity

The air in the test chamber shall be well circulated with a fan without adsorbing or emitting formaldehyde. The air velocity over the surface of the test specimen inside the test chamber shall be controlled as specified in 7.2.3.

6.11 Analytical instrument

A high performance liquid chromatograph (HPLC) shall be used as specified in ISO 16000-3.

7 Test conditions

7.1 General

The test conditions shall comply with 7.2 and 7.3. This test shall be conducted under atmospheric pressure conditions.

7.2 Test conditions of removal performance

7.2.1 Temperature and relative humidity

Indoor-light-active photocatalytic building materials for use in Europe and America shall be tested in accordance with ISO 554 at a temperature of 23 °C ± 2 °C and relative humidity 50 % ± 5 % during the test.

Indoor-light-active photocatalytic building materials for use in Japan shall be tested at a temperature of 28 °C ± 2 °C and relative humidity 50 % ± 5 % during the test.

For indoor-light-active photocatalytic building materials with applications under other climatic conditions, alternative temperatures and air humidity conditions may be used, preferably as specified in ISO 554. State the conditions in the test report.

7.2.2 Supply air quality and background concentration

The background concentration of the supply air to the test chamber and the air prior to spiking with formaldehyde shall be low enough not to interfere with the test. The total VOC (volatile organic compound) background concentration shall be lower than 20 µg/m³. The background concentration of formaldehyde shall be lower the 2 µg/m³. Purified water used for humidification shall not contain interfering VOCs that may affect the test.

7.2.3 Mass transfer coefficient

The mass transfer coefficient in terms of ambient air velocity over the surface of the test specimen inside the test chamber shall be in the range of 15 m/h ± 3 m/h (equivalent to air velocity of 0,25 m/s ± 0,05 m/s) when determined using water vapour.

NOTE 1 The mass transfer coefficient is analogous to convective heat transfer coefficient where geometry and boundary conditions are similar. The mass transfer coefficient can be estimated with a formulation that relates the mass transfer flux to a surface to the concentration differences across the boundary layer. For details concerning the mass transfer coefficient and its measurement method, see Reference [2].

NOTE 2 Removal performance depends on the mass transfer coefficient. Mass transfer coefficient depends on the indoor concentration of the substance, air flow and the surface area of the test specimen.

7.2.4 Air change rate and product loading factor

The air change rate shall be kept constant at 0,50/h ± 0,05/h. The product loading factor shall be in the range of 1,1 m^2/m^3 ± 0,1 m^2/m^3.

For comparison of results from different test chambers, the air change rate, *n*, and the product loading factor, *L*, shall be the same for each chamber. The air change rate, *n*, and the product loading factor, *L*, may affect the removal rate, *r*.

NOTE The selection of area specific air flow rate affects the steady-state concentration of formaldehyde in the chamber air.