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Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for air-purification performance of semiconducting photocatalytic materials —

Part 2: **Removal of acetaldehyde**

Céramiques techniques — Méthodes d'essai relatives à la performance des matériaux photocatalytiques semi-conducteurs pour la purification de l'air —

Partie 2: Élimination de l'acétaldéhyde

Reference number
ISO 22197-2:2019(E)

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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.

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 of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 206, *Fine ceramics*.

This second edition cancels and replaces the first edition (ISO 22197-2:2011), which has been technically revised. The main changes compared to the previous edition are as follows:

— deletion of reference to ISO 2718 (withdrawn) from Clause 2 and 6.5;

— deletion of ISO 4677-1 (withdrawn) from Clause 2 and 8.3.1;

— change of gas flow measurement from dry-gas basis to wet-gas basis in 6.2;

— change of tolerance on dimensions of test piece in Clause 7;

— addition of procedures for removing water-soluble contaminants (8.2);

— addition of criterion for acceptable adsorption of acetaldehyde (9.2).

A list of all parts in the ISO 22197 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for air-purification performance of semiconducting photocatalytic materials —

Part 2:
Removal of acetaldehyde

1 Scope

This document specifies a test method for the determination of the air-purification performance of materials that contain a photocatalyst or have photocatalytic films, 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 irradiation with ultraviolet light (UV-A).

This document is intended for use with different kinds of materials, such as construction materials in flat sheet, board or plate shape, that are the basic forms of materials for various applications.

This document also applies to structured filter materials including honeycomb-form, woven and non-woven fabrics, and to plastic or paper materials if they contain ceramic microcrystals and composites. This document does not apply to powder or granular photocatalytic materials.

This test method is usually applicable to photocatalytic materials produced for air purification. This method is not suitable for the determination of other performance attributes of photocatalytic materials, i.e. decomposition of water contaminants, self-cleaning, antifogging and antibacterial actions. It concerns the removal of acetaldehyde.

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.

ISO 4224, *Ambient air — Determination of carbon monoxide — Non-dispersive infrared spectrometric method*

ISO 10677, *Fine ceramics (advanced ceramics, advanced technical ceramics) — Ultraviolet light source for testing semiconducting photocatalytic materials*

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

ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

ISO 80000-1:2009, *Quantities and units — Part 1: General*

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:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
photocatalyst
substance that performs one or more functions based on oxidization and reduction reactions under photoirradiation, including decomposition and removal of air and water contaminants, deodorization, and antibacterial, self-cleaning and antifogging actions

3.2
photocatalytic materials
materials in which or on which the photocatalyst is added by, for example, coating, impregnation or mixing

Note 1 to entry: Such photocatalytic materials are intended primarily for use as building and road construction materials to obtain the functions described in 3.1.

3.3
zero-calibration gas
air that does not contain pollutants (i.e. in which common pollutants are below 0,01 µl/l and carbon dioxide is below 0,1 µl/l)

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

3.4
standard gas
diluted gas of known concentration supplied in cylinders and certified by an accredited laboratory

3.5
test gas
mixture of air and pollutant(s) of known concentration prepared from a standard gas or a zero-calibration gas, to be used for the performance test of a photocatalytic material

3.6
dark condition
test condition with no light irradiation by the light source for testing and room lighting

4 Symbols

For the purposes of this document, the following symbols apply.

f	air-flow rate converted into that at the standard state (0 °C and 101,3 kPa) (l/min)
ϕ_{A}	volume fraction of acetaldehyde at the reactor exit (µl/l)
ϕ_{AD}	acetaldehyde volume fraction at the reactor exit under dark conditions (µl/l)
ϕ_{A0}	supply volume fraction of acetaldehyde (µl/l)
ϕ_{CO_2}	carbon dioxide (CO_2) volume fraction generated by UV irradiation (µl/l)
$\phi_{CO_2,L}$	CO_2 volume fraction at the reactor exit under UV irradiation (µl/l)
$\phi_{CO_2,D}$	CO_2 volume fraction at the reactor exit under dark conditions (µl/l)
$\phi_{CO_2,Dpost}$	CO_2 volume fraction in the dark after UV irradiation (µl/l)
$\phi_{CO_2,Dpre}$	CO_2 volume fraction in the dark before UV irradiation (µl/l)
n_{A}	quantity of acetaldehyde removed by the test piece (µmol)

n_{CO_2} quantity of CO_2 converted from acetaldehyde (μmol)

R_A the removal percentage, by test piece, of acetaldehyde (%)

R_{CO_2} the conversion from acetaldehyde to CO_2 (%)

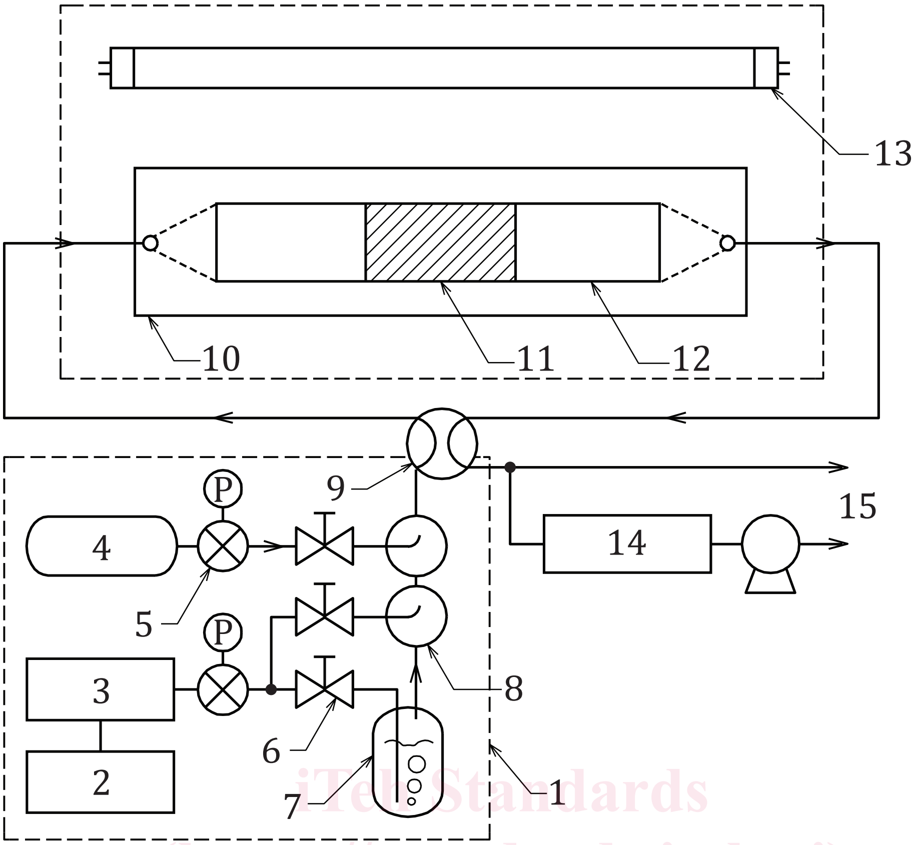
5 Principle

This document concerns the development, comparison, quality assurance, characterization, reliability, and design data generation of photocatalytic materials (see Reference [1]). The method described is intended to obtain the air-purification performance of photocatalytic materials by exposing a test piece to model polluted air under irradiation by ultraviolet (UV) light (see Reference [2]). Acetaldehyde (CH_3CHO) is chosen as a typical volatile organic compound (VOC) with lower molecular mass and offensive odour[3]. The test piece, put in a flow-type photoreactor, is activated by UV irradiation, and adsorbs and oxidizes gas-phase acetaldehyde to form carbon dioxide (CO_2) and other oxidation products. The air-purification performance is determined from the amount of acetaldehyde, in percent, adsorbed by the test piece, in micromoles (μmol). The simple adsorption by the test piece (not due to photocatalysis) is evaluated by the tests in the dark. However, some test pieces adsorb acetaldehyde very strongly, and a stable concentration of acetaldehyde may not be attained in the designated time of test. The photocatalytic activity may depend on physical and chemical properties of pollutants mainly due to the adsorption process involved. For a better evaluation of air purification performance of photocatalytic materials, it is recommended that one or more suitable test methods are combined as described in other parts of the ISO 22197 series.

6 Apparatus

6.1 Test equipment

The test equipment enables a photocatalytic material to be examined for its pollutant-removal capability by supplying the test gas continuously, while providing photoirradiation to activate the photocatalyst. It is the same as that used in the test method for the removal of nitric oxide (ISO 22197-1[2]) and consists of a test gas supply, a photoreactor, a light source and pollutant-measurement equipment. Since low concentrations of pollutants are to be tested, the system shall be constructed with materials of low adsorption and resistant to UV radiation (e.g. acrylic resin, borosilicate glass). An example of a testing system is shown in Figure 1.



Key

1	test gas supply	9	4-way valve
2	air compressor	10	photoreactor
3	air-purification system	11	test piece
4	standard gas (pollutant)	12	air-tight optical window
5	pressure regulator	13	light source
6	mass-flow controller	14	analyser
7	humidifier	15	vent
8	gas mixer		

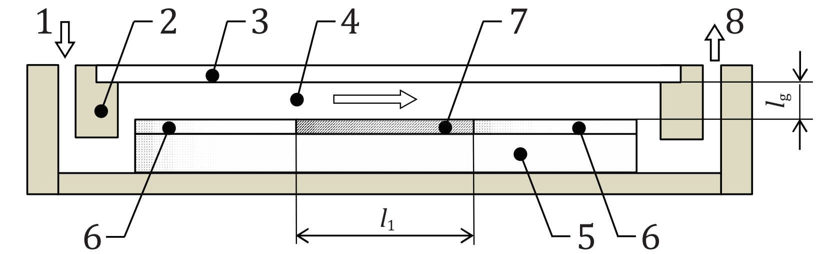
Figure 1 — Schematic diagram of test equipment

6.2 Test gas supply

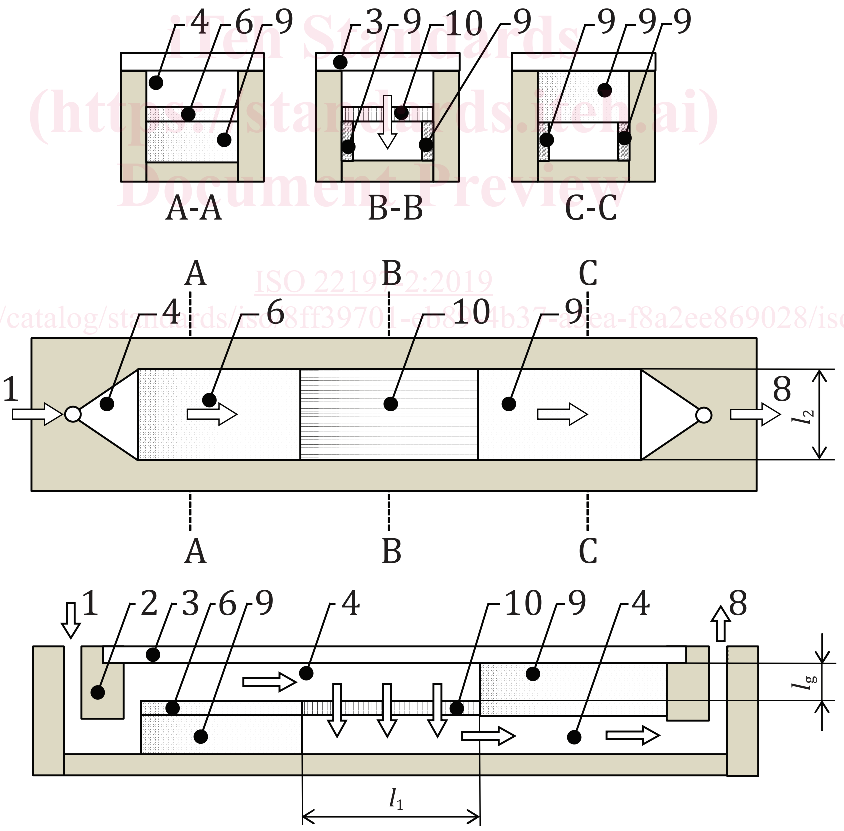
The test gas supply provides air polluted with model contaminant at a predetermined concentration, temperature and humidity, and supplies it continuously to the photoreactor. It consists of flow regulators, a humidifier, gas mixers and so forth. The flow rate of each gas should be within 5 % of the designated value, which is easily attained by using thermal mass-flow controllers with knowledge of the temperature and gas type at calibration in accordance with ISO 6145-7[4]. The expression of gas flow rate in this document is that converted to the standard state (0 °C and 101,3 kPa). Typical capacities of flow controller for pollutant gas, dry air and wet air are 100 ml/min, 1 000 ml/min and 1 000 ml/min, respectively. The standard acetaldehyde gas before dilution, normally balanced with nitrogen in a cylinder, shall have a volume fraction of 50 µl/l to 250 µl/l. Synthetic air (N_2 + O_2, such as that supplied in cylinders) shall be used for dilution when the CO_2 from acetaldehyde is also measured.

6.3 Photoreactor

The photoreactor holds a planar test piece within a 50 mm wide trough, with its surface parallel to an optical window for photoirradiation. The reactor shall be fabricated from materials that adsorb little test gas and withstand irradiation of near-UV light. The test piece shall be separated from the window by a 5,0 mm ± 0,5 mm-thick air layer. The test gas shall pass only through the space between the test piece and the window. This gap shall be accurately set up according to the thickness of the test piece, for example, by using height-adjusting plates with different thicknesses, as shown in Figure 2 a). When a filter-type material is tested, an alternative type of test-piece holder shall be used, which holds the test piece while allowing the test gas to pass through the cells of the filter under irradiation [Figure 2 b)]. Quartz or borosilicate glass that absorbs minimal light at wavelengths longer than 300 nm should be used for the window.



a) For flat test pieces



b) For filter-type test pieces

test piece length l_1	test piece width l_2	air layer thickness l_g
99,0 ± 1,0 mm	49,0 ± 1,0 mm	5,0 ± 0,5 mm

Key

1 test gas inlet
2 baffle
3 air-tight optical window
4 flow channel
5 height-adjusting plate
6 auxiliary plate
7 test piece (flat-type)
8 test gas outlet
9 test piece holder
10 test piece (filter-type)

Figure 2 — Cross-sectional view of photoreactor

6.4 Light source

The light source shall provide UV-A irradiation within a wavelength range of 300 nm to 400 nm. Suitable sources include the so-called black light (BL) and black light blue (BLB) fluorescent lamps, with a maximum at 351 nm or 368 nm, as specified in ISO 10677, and xenon arc lamps with optical filters that block radiation below 300 nm. In the case of a xenon arc lamp, a cooling system shall be used in accordance with ISO 10677. The test piece shall be irradiated uniformly through the window by the light source. In the case of testing filter-type photocatalysts, the light source shall irradiate one end of the test piece. A light source that requires warming up shall be equipped with a shutter. The distance between the light source and the reactor shall be adjusted so that the UV irradiance (300 nm to 400 nm) at the sample surface is 10 W/m^2 ± 0,5 W/m^2. This distance shall be determined independently without using the photoreactor. A UV radiometer in conformity with ISO 10677 shall be put behind the optical window or its equivalent, at the same level as the test piece to be tested. The irradiance along the length of the test piece shall also be constant within ±5 %. The reactor shall be shielded from external light if necessary.

6.5 Analytical system for acetaldehyde

The concentration of acetaldehyde shall be determined by gas chromatography or 2,4-dinitrophenylhydrazine-derivatized high-performance liquid chromatography (DNPH/HPLC).

In the case of gas chromatography, either a packed column or capillary column can be used, as long as it can separate lower organic compounds. The detection shall be made by either a flame ionization detector (FID) or photoionization detector (PID). The test gas is sampled with a gastight syringe. However, use of a six-way valve is recommended for reproducible and automatic sampling. The flow diagram when a six-way valve is used is shown in Figure 3. A small sampling pump continuously ventilates the metering tube with the test gas. The pump is stopped when the test gas is sampled by switching the six-way valve. The volume of the metering tube is typically 0,5 ml, but it shall be determined by the sensitivity of the analytical system.

In the case of the DNPH/HPLC method, the reagents, equipment and procedure specified in ISO 16000-3 shall be used.