PD CEN/TS 16599:2014

BSI Standards Publication

Photocatalysis — Irradiation conditions for testing photocatalytic properties of semiconducting materials and the measurement of these conditions

bsi.

...making excellence a habit.™

National foreword

This Published Document is the UK implementation of CEN/TS 16599:2014.

The UK participation in its preparation was entrusted to Technical Committee RPI/13, Advanced technical ceramics.

A list of organizations represented on this committee can be obtained on request to its secretary.

Published by BSI Standards Limited 2014

ISBN 978 0 580 82658 0
ICS 25.220.20

This Published Document was published under the authority of the Standards Policy and Strategy Committee on 30 April 2014.

Amendments/corrigenda issued since publication

Date	Text affected

TECHNICAL SPECIFICATION
SPÉCIFICATION TECHNIQUE
TECHNISCHE SPEZIFIKATION

CEN/TS 16599

March 2014

ICS 25.220.20

English Version

Photocatalysis - Irradiation conditions for testing photocatalytic properties of semiconducting materials and the measurement of these conditions

Photocatalyse - Détermination des conditions d'irradiation pour tester les propriétés photocatalytiques de matériaux semi-conducteurs

Photokatalyse - Bestrahlungsbedingungen zum Prüfen photokatalytischer Eigenschaften von halbleitenden Werkstoffen und die Messung dieser Bedingungen

This Technical Specification (CEN/TS) was approved by CEN on 14 October 2013 for provisional application.

The period of validity of this CEN/TS is limited initially to three years. After two years the members of CEN will be requested to submit their comments, particularly on the question whether the CEN/TS can be converted into a European Standard.

CEN members are required to announce the existence of this CEN/TS in the same way as for an EN and to make the CEN/TS available promptly at national level in an appropriate form. It is permissible to keep conflicting national standards in force (in parallel to the CEN/TS) until the final decision about the possible conversion of the CEN/TS into an EN is reached.

CEN members are the national standards bodies of Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and United Kingdom.

EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

CEN-CENELEC Management Centre: Avenue Marnix 17, B-1000 Brussels

Contents

Page

Foreword

This document (CEN/TS 16599:2014) has been prepared by Technical Committee CEN/TC 386 “Photocatalysis”, the secretariat of which is held by AFNOR.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

CEN (the European Committee for Standardization) is a European committee of national standards bodies (CEN member bodies). The work of preparing European Standards is normally carried out through CEN 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.

European organizations, governmental and non-governmental, in liaison with CEN, also take part in the work. The main task of Technical Committees is to prepare European Standards. Drafts adopted by the Technical Committees are circulated to the member bodies for voting. Publication as a European Standard requires approval by at least 71 % of the member bodies casting a vote.

Safety statement

Persons using this document should be familiar with the normal laboratory practice, if applicable. This document cannot address all of the safety problems, if any, associated with its use. It is the responsibility of the user to establish appropriate safety and health practices and to ensure compliance with any regulatory conditions.

Environmental statement

It is understood that some of the material permitted in this standard may have negative environmental impact. As technological advantages lead to better alternatives for these materials, they will be eliminated from this standard to the extent possible.

At the end of the test, the user of the standard will take care to carry out an appropriate disposal of the wastes, according to local regulation.

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to announce this Technical Specification: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Introduction

Photocatalysis is a very efficient advanced oxidation technique which enables the production of hydroxyl radicals (·OH) or perhydroxyl radicals (·OOH), capable of partly or completely mineralising/oxidising the majority of organic compounds. Its principle is based on the simultaneous actions of photons and of a catalytic layer which allows degradation of molecules. The most commonly used photocatalyst is titanium dioxide (TiO_2), the latter being thermodynamically stable, non-toxic and economical. It can be used in powder form or deposited on a substrate (glass fibre, fabrics, plates/sheets, etc.). The objective is to introduce performance standards for photo-induced effects (including photocatalysis). These standards will mainly concern test and analysis methods.

1 Scope

This Technical Specification prescribes the conditions for irradiating photocatalytic surfaces in order to perform photocatalytic efficiency tests. In addition, the measurement and documentation of these irradiation conditions with respect to the spectral distribution, irradiance and homogeneity are given.

2 Symbols and abbreviations

APD	avalanche photodiode
A (λ)	decadic absorbance
CA	chemical actinometry
E	irradiance
FWHM	full width at half maximum
h_d	height difference
h_max	maximum height difference
h_s	measurement plane
LED	light emitting diode
PC-A	photocatalytic amber
PC-B	photocatalytic blue
PC-C	photocatalytic cyan
PC-G	photocatalytic green
PC-R	photocatalytic red
PC-U	photocatalytic ultraviolet
PC-UC	photocatalytic ultraviolet C
PC-V	photocatalytic violet
QP_abs (λ)	total amount of absorbed photons
q_p° (λ)	incident photon flux
λ	wavelength
φ (λ)	quantum yield

In Annex A, further examples concerning literature, terms and definitions, quantities and figures are listed for information.

3 Specification of spectral areas and irradiance values

As shown in Table 1, different spectral areas in combination with the specified irradiance should be used for irradiation during photocatalytical analysis. The test procedures themselves are described in their according standards, e.g. ISO 22197-1 [6] for the abatement of nitrogen monoxide.

Table 1 — Specification of spectral areas and irradiance values

Range	Abbreviation	Colour	Peak nm	$_{max}$FWHM nm	Cut-on-Limit E < 2 % nm	Cut-off-Limit E < 5 % nm	Irradiance[a] W/m^2
UV	*PC-UC*	Ultraviolet C	254 ± 5	not defined	not defined	not defined	not defined
	PC-U	Ultraviolet	365 ± 5	20	345	385	10,0 (± 10 %)
VIS	*PC-V*	Violet	405 ± 5	15	370	440	9,0 (± 7 %)
	PC-B	Blue	450 ± 5	20	400	495	8,1 (± 5 %)
	PC-C	Cyan	500 ± 5	27	440	560	7,3 (± 5 %)
	PC-G	Green	530 ± 5	30	465	595	6,8 (± 5 %)
	PC-A	Amber	590 ± 5	15	555	620	6,2 (± 5 %)
	PC-R	Red	630 ± 5	15	595	655	5,8 (± 5 %)

NOTE 1 For more information about the definition of UV- and VIS-range see reference [7].

NOTE 2 The above mentioned irradiance values are named as guidelines for the level of irradiance. As well as the unification to use the same photon flux is a suggestion in order to have a valid basis on the same concentration of photogenerated active species with respect to the typical heterogeneous catalytic reactions standing behind photocatalytic reactions. If special photocatalytic measurements need to use different parameters, it is important that these deviations be named and refer to this Technical Specification. The basis of 10 W/m^2 UVA-radiation is a compromise of outside day and night irradiance during the whole year in Central Europe and therefore also a compromise between Northern Europe, e.g. Scandinavia, which usually has less irradiance, and Southern Europe, e.g. Mediterranean Area, which usually has more irradiance. This is the same assumption as to have a compromise between indoor (most of the time lower) and outdoor (most of the time higher) irradiation conditions.

[a] A min. 75 % of the irradiance has to be within FWHM and a min. 93 % of the irradiance has to be within Cut-on- and Cut-off-Limit. The used irradiance values should represent the same flux of photons within the described part of the spectra.

Presently only *PC-U*, *PC-V*, *PC-B*, *PC-C* and *PC-G* are important for photocatalytic applications. *PC-A* and *PC-R* are only important for future innovations in photocatalytic materials, which use these defined wavelengths for photo-oxidation processes. Examples of available and suitable filters and LEDs which fulfil these conditions are shown in A.3 and A.4.

4 Lamp types and filters

4.1 Examples of different lamp types

4.1.1 Xenon lamps

In a pure xenon lamp, the light generation volume is cone-shaped, and the luminous intensity falls off exponentially moving from cathode to anode. Electrons passing through the plasma cloud strike the anode, causing it to heat. Pure xenon short-arc lamps have a "near daylight" spectrum, that is, the light output of the lamp is relatively flat over the entire colour spectrum. All xenon short-arc lamps generate significant amounts of ultraviolet radiation while in operation. Xenon has strong spectral lines in the UV bands, and these readily pass through the fused quartz lamp envelope. Unlike the borosilicate glass used in standard lamps, fused quartz does not attenuate UV radiation. The UV radiation released by a short-arc lamp can cause a secondary problem of ozone generation. Equipment that uses short-arc lamps as the light source shall contain UV radiation and prevent ozone build-up. Many lamps have a low-UV blocking coating on the envelope and are sold as "Ozone Free" lamps. Some lamps have envelopes made out of ultra-pure synthetic, which roughly doubles the cost, but which allows them to emit useful light into the so-called vacuum UV region. These lamps are normally operated in a pure nitrogen atmosphere.

NOTE Xe-Arc-bow lamps show the disadvantage when broader areas than 100*100 mm^2 have to be irradiated homogeneously.

4.1.2 Halogen lamps

A halogen lamp, also known as a tungsten halogen lamp, is an incandescent lamp with a tungsten filament contained within an inert gas and a small amount of a halogen such as iodine or bromine. The combination of the halogen gas and the tungsten filament produces a chemical reaction known as a halogen cycle which increases the lifetime of the filament and prevents darkening of the bulb by redepositing tungsten from the inside of the bulb back onto the filament. Because of this, a halogen lamp can be operated at a higher temperature than a standard gas-filled lamp of similar power and operating life. The higher operating temperature results in light of a higher colour temperature (blue shift). Because of their smaller size, halogen lamps can be used advantageously with optical systems that are more efficient in how they cast emitted light. Like all incandescent light bulbs, a halogen lamp produces a continuous spectrum of light, from near ultraviolet to deep into the infrared.

4.1.3 Fluorescence lamps

A fluorescent lamp or fluorescent tube is a gas-discharge lamp that uses electricity to excite mercury vapour. The excited mercury atoms produce short-wave ultraviolet radiation that then causes a phosphor to fluorescence, producing visible light. A fluorescent lamp converts electrical power into useful light more efficiently than an incandescent lamp. Lower energy cost typically offsets the higher initial cost of the lamp. The lamp fixture is more costly because it requires a ballast to regulate the current through the lamp. While larger fluorescent lamps have been mostly used in commercial or institutional buildings, the compact fluorescent lamp is now available in the same popular sizes as incandescent and is used as an energy-saving alternative in homes.

NOTE 1 The United States Environmental Protection Agency classifies fluorescent lamps as hazardous waste, and recommends that they be segregated from general waste for recycling or safe disposal.

Fluorescence lamps have very different spectral distributions, but typically a combination of three or five different phosphors lead to a three- or five-band fluorescent lamp. Each phosphor used gives characteristic emission spectra. Comparable peak wavelengths of the phosphors might also shift during the period of use due to ageing effects (red shift). Some examples for different emission spectra of fluorescence tubes are given in A.6.

NOTE 2 Due to the different emission bands of various fluorescence tubes, a comparison of photocatalytic activities will be very difficult.

4.1.4 Mercury vapour lamps

A mercury vapour lamp is a gas discharge lamp that uses mercury in an excited state to produce light. The arc discharge is generally confined to a small fused quartz arc tube mounted within a larger borosilicate glass bulb. The outer bulb may be clear or coated with a phosphor; in either case, the outer bulb provides thermal insulation, protection from ultraviolet radiation, and a convenient mounting for the fused quartz arc tube. Mercury vapour lamps (and their relatives) are often used because they are relatively efficient. Phosphor coated bulbs offer better colour rendition than either high- or low-pressure sodium vapour lamps. Mercury vapour lamps also offer a very long lifetime, as well as intense lighting for several special purpose applications.

NOTE Hg-low-pressure lamps are only usable for PC-UC.

4.1.5 Light emitting diodes (LED)

A light-emitting diode is a semiconductor light source. LEDs are used as indicator lamps in many devices and are increasingly used for other lighting. When a light-emitting diode is switched on, electrons are able to recombine with electron holes within the device, releasing energy in the form of photons. This effect is called electroluminescence and the colour of the light (corresponding to the energy of the photon) is determined by the energy gap of the semiconductor. A LED is often small in area (less than 1 mm^2), and integrated optical components may be used to shape its radiation pattern. LEDs present many advantages over incandescent light sources including lower energy consumption, longer lifetime, improved robustness, smaller size, faster switching, and greater durability and reliability. LEDs powerful enough for room lighting are relatively expensive and require more precise current and heat management than compact fluorescent lamp sources of comparable output.

NOTE Light emitting diodes are available in all spectral ranges defined in Clause 3.

4.1.6 Sunlight

Sunlight, in the broad sense, is the total frequency spectrum of electromagnetic radiation emitted from sun. On earth, sunlight is filtered through the earth's atmosphere, and solar radiation is obvious as daylight when the sun is above the horizon. When the direct solar radiation is not blocked by clouds, it is experienced as sunshine, a combination of bright light and radiant heat. When it is blocked by the clouds or reflects off other objects, it is experienced as diffused light. The World Meteorological Organization uses the term "sunshine duration" to mean the cumulative time during which an area receives direct irradiance from the sun of at least 120 W/m^2. Sunlight may be recorded using a sunshine recorder, pyranometer or pyrheliometer. Bright sunlight provides irradiance of approximately 700 W/m^2 to 900 W/m^2 at the earth's surface. Sunlight is a key factor in photosynthesis, a process vital for life on earth.

NOTE Sunlight is not applicable for testing due to fluctuations in intensity, weathering and changes of angle of incidence.

4.2 Controlling of the ageing behaviour of the used lamp

Lamps have to be checked every 500 h of operation regarding the spectral distribution and the output power (see also irradiance level in Table 1). If there is a shift, e.g. for fluorescence tubes, of more than 10 nm, lamps have to be replaced by new ones. If there is a loss in output power, lamps also have to be replaced by new ones or if it is possible the output power has to be adjusted by changing the distance between the lamp and the sample.

4.3 Filters

4.3.1 Cut-on/Cut-off-filters for irradiation of large areas

A long-pass-filter (cut-on-filter) is a coloured glass or a plastic foil filter that attenuates shorter wavelengths and transmits (passes) longer wavelengths over the active range of the target spectrum (ultraviolet, visible, or infrared). In contrast, a short-pass-filter (cut-off-filter) blocks longer wavelengths and transmits shorter wavelengths. Long-pass-filters and short-pass-filters, which can have a very sharp slope (referred to as edge filters), are described by the cut-on respectively cut-off wavelength at 50 % of peak transmission.

4.3.2 Band-pass-filters for irradiation of small areas

A band-pass-filter is mainly an interference filter which works to mask out frequencies that are too low or too high, giving easy passage only to frequencies within a certain range. The largest available commercial dimensions for band-pass-filters are limited to (50 × 50) mm^2. Dimensions for customers' specifications are very expensive in manufacturing. Therefore, a combination of a long-pass- and a short-pass-filter could simulate a band-pass-filter with respect to the possibility of irradiating larger areas.

4.3.3 Interference filters

Interference is a characteristic of the wave nature of electromagnetic radiation. Two or more coherent wave trains of the same wavelength and polarisation state that are superimposed enhance or compensate each other, depending on the phase relationship and amplitudes of the electric field strength. These filters utilize the interference effect to transmit or reflect certain spectral ranges of the electromagnetic radiation. Hereto numerous thin layers with differing refractive indices are applied to a substrate. The optical thicknesses of these layers are usually a quarter of a given design wavelength or multiples thereof. When electromagnetic radiation encounters such a multilayer system, the incident beam is split at every interface between two layers of differing refractive indices into a transmitted and a reflected beam. This process is repeated at every successive interface, resulting in the formation of numerous superimposing secondary beams that give rise to interference, either in a constructive or a destructive manner. A wide variety of spectral characteristics with high transmission or high reflection ratings can be produced by varying the nature, number, thicknesses and order of the layers. The coatings of the interference filters are manufactured by the process of vapour deposition under high vacuum. In the case of so-called "soft” coatings, additional measures are normally taken to protect the filters from damage e.g. by handling or from moisture. This is usually achieved by supplementary cementing with suitable glass. The upper temperature limit for these filters is essentially determined by the nature of the optical cement used. Within certain areas of the UV spectrum, it is not possible to use optical cements due to the inherent absorption involved. In such cases, the coated substrates are fitted into appropriate mounts and protected by suitable glasses. In the case of so-called "hard” coatings, the layers of which normally consist of very stable metal oxides, there is generally no need for additional protection. Depending on the substrate selected, interference filters with hard coatings can be operated at temperatures up to approximately 350 °C.

5 Diffusers

Commonly used diffuser technologies include prismatic glass integrating bars, ground glass, opal glass, holographic diffusers and diffractive diffusers. Prismatic glass integrating bars, though sometimes used in high end systems, are limited in capability, are expensive, and occupy a great deal of precious space. Ground and opal glass scatter light equally in all directions but offer limited light-control capabilities. In addition, efficiency is often very poor with these simple diffusers. A holographic diffuser is a step ahead of these diffusers and enables the production of simple light distribution patterns. Holographic diffusers, however, have limited control over the light distribution pattern. In general, only round or elliptical patterns can be produced and only with non-uniform intensity variation, typically of a Gaussian nature. In terms of general beam shaping capability, diffractive elements can shape an input beam arbitrarily. These are mostly limited to monochromatic applications with coherent light sources. Diffractive elements are also limited to narrow diffusion angles due to fabrication limitations, can be strongly sensitive to input beam variations, and present the well-known problem of zero order, a bright spot co-linear with the incident beam. In many applications, the zero order is unacceptable and the requirement of single wavelength operation is very restricting. Diffusers are found in many applications where a bright light source is used to create uniform irradiation over a broad area. Applications include outdoor lighting, rear projection televisions, and consumer electronic displays. Traditional ground or opal glass diffusers are inefficient and have limited capabilities when it comes to controlling the shape of the irradiated area. More modern holographic diffusers can typically be made so that round or elliptical areas are irradiated but the intensity of the radiation is usually only Gaussian within a small angular width. In addition, holographic diffusers are often limited to monochromatic applications using coherent light.

6 Measuring systems

6.1 General

The used physical measuring systems have to be calibrated in the same range of later use, where the irradiation sources are available. All incident radiation shall not be cosine function corrected with respect to the incident angle.

NOTE In case of using handheld devices (handheld meter), operate them on a power plug or with fully loaded batteries as not fully or differently charged batteries might have severe influence on the entire data acquisition properties of the device.

6.2 Thermopile-Sensors

A heat flux sensor is a transducer that generates an electrical signal proportional to the total heat rate applied to the surface of the sensor. The measured heat rate is divided by the surface area of the sensor to determine the heat flux. The heat flux can have different origins; in principle, convective, radiative as well as conductive heat can be measured. Heat flux sensors are known under different names, such as heat flux transducers, heat flux gauges, heat flux plates. Some instruments actually are single-purpose heat flux sensors like pyranometers for solar radiation measurement. Other heat flux sensors include Gardon gauges (also known as a circular-foil gauge), thin-film thermopiles, and Schmidt-Boelter gauges. In SI units, the heat rate is measured in W, and the heat flux is computed in W/m^2.

Thermopile sensors should not be used without an additional aperture in order to avoid unwanted surface heating of the housing of the item; this aperture should at least be smaller than the original aperture to prevent the sensor from scattered light due to the use of divergent light sources or reflections in the test chamber.

6.3 Calibrated Si-Photodiodes

Photodiodes are semiconductor radiation sensors that generate a current or voltage when the P-N-junction in the semiconductor is irradiated by light. The term photodiode can be broadly defined to include even solar batteries, but it usually refers to sensors used to detect the irradiance. Photodiodes can be classified by function and construction:

a) PN photodiode,

b) PIN photodiode,

c) Schottky-type photodiode,

d) APD (Avalanche photodiode).

All of these types provide the following features and are widely used for the detection of the intensity of radiation:

1) excellent linearity with respect to incident radiation;

2) low noise;

3) wide spectral response;

4) mechanically rugged;

5) compact and lightweight;

6) long life.

For normal photodiodes, the cut-off wavelength is 320 nm, whereas for UV-enhanced photodiodes it is 190 nm. The cut-off wavelength is determined by the intrinsic material properties of the photodiode, but it is also affected by the spectral transmittance of the window material (borosilicate glass, plastic resin or quartz glass) and diffusor type.

6.4 Quantum counter based on fluorescence

A quantum counter is an emitting medium with a quantum yield independent of the excitation energy over a defined spectral range (e.g. concentrated rhodamine 6G solutions between 300 nm and 600 nm). It is also used for devices producing an electrical signal proportional to the photon flux absorbed in a medium.

6.5 Chemical actinometry

An actinometer is a chemical system or a physical device by which the number of photons in a beam absorbed into the defined space of a chemical reactor can be determined integrally or per time.

A **chemical actinometer (CA)** or dosimeter is a chemical system (fluid, gas, solid, or in a microheterogeneous environment) that undergoes a light-induced reaction (at a certain wavelength, λ) for which the quantum yield, φ (λ), is accurately known. Measuring the reaction rate allows the calculation of the absorbed photon flux.

The incident photon flux q_p° is calculated from the relation QP (abs, λ) = q_p° (λ) $(1–10^{–A\ (\lambda)})$, provided that the decadic absorbance A (λ) is constant ± 10 % during the irradiation time. Should this not be the case, integration of the differential absorbance over time would be necessary. The easiest case is for QP (abs, λ) = q_p° (λ) for total absorption during the whole irradiation period. Determination of conversion to the products affords the total number of photons absorbed by the liquid or gas volume or solid surface, which may have any form or geometry.

The quantum yield of a photochemical reaction is defined as φ (λ) = the number of events, e.g. molecules changed, formed, or destroyed, divided by the number of absorbed photons of that particular wavelength in the same period of time. Calibration of an actinometer is done by applying a calibration lamp or by absolute measurement of irradiance (using, e.g. a calibrated radiometer, a calorimeter, or a photodiode). Photothermal methods are often used to calibrate actinometers in absolute terms. In a chemical actinometer, photochemical conversion is directly related to the number of photons absorbed because the chemical action of light means reversible or irreversible chemical change, i.e. destruction or build-up of molecules and, consequently, of their properties such as their spectrum.

Chemical actinometry has been employed for about 70 years in photochemistry as a relatively simple and accurate method for radiation measurement. In contrast to the physical detectors, well-established CAs lead to accurate absolute radiation measurements, provided that they are employed according to the recommended procedures. These CAs have been proven reproducible and do not demand any recalibration.

6.6 Spectral radiometers

A diode or CCD-array spectroradiometer has to be used for qualitative characterization of the spectral distribution of the used lamp. For precise, absolute measurements of the irradiance, a double-monochromator spectroradiometer with a photomultiplier detector shall be employed. This radiometer (including all equipment) shall be calibrated with standard lamps of which the absolute irradiance is certified (PTB, NIST, etc.). Calibrations are only useful and reproducible if the measurement of the irradiance for photocatalytic tests is done in the same way as the calibration was done (same temperature, distance from lamp to measurement head and the lamp type, etc.).

7 Homogeneous irradiation of areas

7.1 Homogeneity of intensity

The following criteria of homogeneity of intensity shall be used over the whole sample area and over the whole measuring time. The radiation is considered homogeneous, if the measurement spots (defined in 7.2) show a percentage variation compared to the average value of less than:

a) Samples up to 100 mm × 100 mm

Inhomogeneity < ± 5 %

b) Samples up to 500 mm × 500 mm

Inhomogeneity < ± 10 %

c) Samples up to 1 000 mm × 1 000 mm

Inhomogeneity < ± 15 %

7.2 Number and local positions of the measurement points

The number and local positions of the measurement points should be in relation towards the specimen.

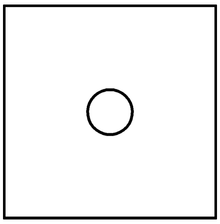


Figure 1 — Samples up to 30 mm x 30 mm: measure 1 spot in the centre

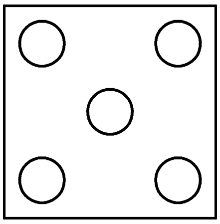


Figure 2 — Samples from 30 mm x 30 mm up to 100 mm x 100 mm: measure 5 spots

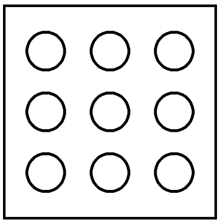


Figure 3 — Samples from 100 mm x 100 mm up to 200 mm x 200 mm: measure 9 spots

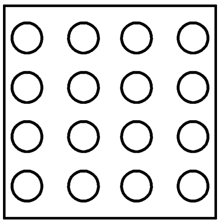


Figure 4 — Samples from 200 mm x 200 mm up to 500 mm x 500 mm: measure 16 spots

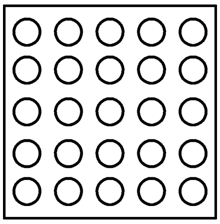


Figure 5 — Samples from 500 mm x 500 mm up to 1 000 mm x 1 000 mm: measure 25 spots

Each spot has to be measured three times to generate the average value.

7.3 Position of the measurement plane

It is possible to have plain, rough, structured and curved sample surfaces. For plain (see Figure 6) and rough samples (see Figure 7) (height difference (h_d) ≤ 3 mm) the measurement plane is at the top of the sample surface (h_s).

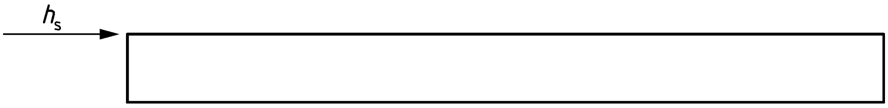


Figure 6 — Plane surface

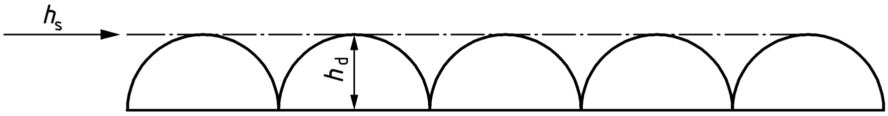


Figure 7 — Rough surface

For structured samples (see Figure 8) (height difference (h_d) ≥ 3 mm) the measurement plane is at the half-height ($0{,}5 \times h_d$) of the structures.

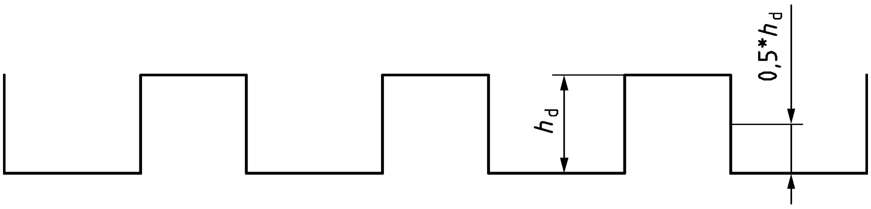


Figure 8 — Structured samples

For curved samples (see Figure 9) a maximum height difference (h_{max}) from the centre (C) to the edge (E) has to be determined, the measurement plane is at the half maximum ($0,5*h_{max}$):

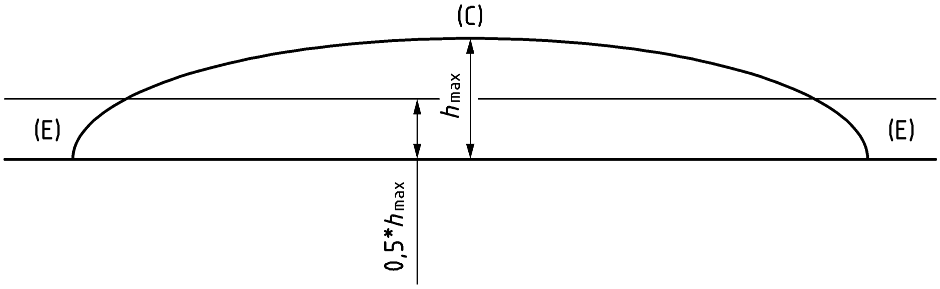


Figure 9 — Curved surface

NOTE With respect to real application surfaces, the following limits of maximum height are recommended:

- samples up to 30 mm × 30 mm a maximum height difference (h_{max}) of 3 mm;
- samples from 30 mm × 30 mm up to 100 mm × 100 mm a maximum height difference (h_{max}) of 5 mm;
- samples from 100 mm × 100 mm up to 200 mm × 200 mm a maximum height difference (h_{max}) of 10 mm;
- samples from 200 mm × 200 mm up to 500 mm × 500 mm a maximum height difference (h_{max}) of 20 mm;
- samples from 500 mm × 500 mm up to 1 000 mm × 1 000 mm a maximum height difference (h_{max}) of 40 mm.

8 Test report

The following information shall be included:

a) kind of lamp used (catalogue number, manufacture’s name, powerage, etc.);

b) kind of filter and/or reflector and/or diffuser used;

c) spectrum of the incident radiation;

d) kind of setup used for the determination of irradiance;

e) copy of the certificate of calibration of the used sensor;

f) absolute irradiance (W/m^2) and spectral range for the measurement (see Clause 3);

g) dimensions, roughness or structuring of the sample;

h) a reference to this CEN/TS;

i) any unusual features noted during the irradiating of the photocatalytic surface.

Annex A
(informative)

Informative examples and definitions

A.1 Informative Terms and definitions

A.1.1 Standard irradiation conditions

Standard irradiation will be understood as normal, not artificially increased, irradiation conditions for the purpose to establish ambient lighting conditions for photocatalytic applications. These conditions are to be found outdoors (standard sunlight, as well as artificial irradiation for streets, tunnels, places, etc.) or indoors (standard daylight mixture of natural sunlight derived through windows and artificial ambient irradiation). The wavelength for standard irradiation conditions will be limited between 305 nm (lower limit due to irradiation on earth at sea level) and 780 nm (upper limit due to border between visible light and infrared radiation) and therefore will focus on photocatalytic effects and not on photolysis effects or others. The irradiance will be confined at maximum of central European summer sunlight noon conditions (equivalent to 900 W/m^2 (UV+Vis+IR) or 45 W/m^2 = 4,5 mW/cm^2 UV and 450 W/m^2 = 45 mW/cm^2 Vis) (see [8] AM1,5 spectrum) and at minimum of standard interior irradiation conditions in living rooms (0,75 W/m^2 Vis).

A.1.2 Irradiation conditions for specific applications

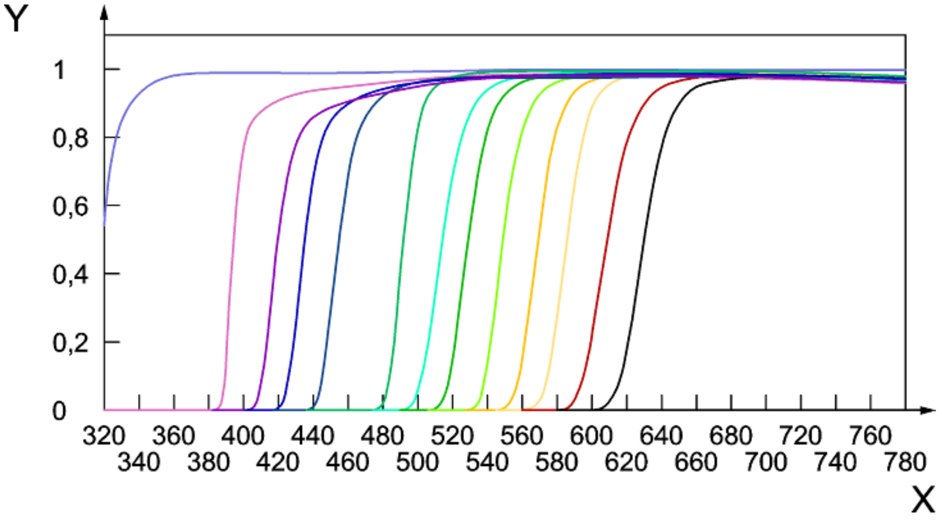
Irradiation conditions for specific applications will be understood as higher than the equivalent standard irradiation conditions, artificially increased in spectral distribution and/or in irradiance with the purpose to increase the photocatalytic efficiency. These irradiation conditions are to be found, e.g. in tunnels or air treatment systems. The wavelength of irradiation for specific application will be limited between 220 nm (lower limit to avoid the production of ozone) and 780 nm (upper limit due to border between visible light and infrared radiation) and therefore give the ability of synergistic effects of photocatalysis, for example with photolysis. The minimum irradiance by definition will be the equivalent standard irradiance. The maximum irradiance will only be limited by technical availability.

Table A.1 — Radiometric symbols and units

Designation	Symbol	derived SI unit	Notes
Radiant energy	Q_e	Joule [J]	energy
Radiant flux	Φ_e	watt [W]	radiant energy per unit time, also called radiant power
Spectral concentration of radiant flux	$\Phi_{e\lambda}$	watt per metre [W·m^{-1}]	radiant flux per wavelength, dE/dλ
Radiant intensity	I_e	watt per steradian [W·sr^{-1}]	radiant flux per unit solid angle
Spectral concentration of radiant intensity	$I_{e\lambda}$	watt per steradian per metre [W·sr^{-1}·m^{-1}]	radiant intensity per wavelength

Designation	Symbol	derived SI unit	Notes
Radiance	L_e	watt per steradian per square metre [W·sr^{-1}·m^{-2}]	radiant flux per unit solid angle per unit projected source area
Spectral concentration of radiance	$L_{e\lambda}$	watt per steradian per cubic metre [W·sr^{-1}·m^{-3}]	commonly measured in W·sr^{-1}·m^{-2}·nm^{-1} with surface area
Irradiance	E_e	watt per square metre [W·m^{-2}]	radiant flux incident on a surface
Spectral irradiance	$E_{e\lambda}$	watt per cubic metre [W·m^{-3}]	commonly measured in W·m^{-2}·nm^{-1}, known as solar flux unit
Radiant exposure	H_e	joule per square metre [J·m^{-2}]	= integral (Irradiance per time)

A.2 Examples for available cut-on-filters

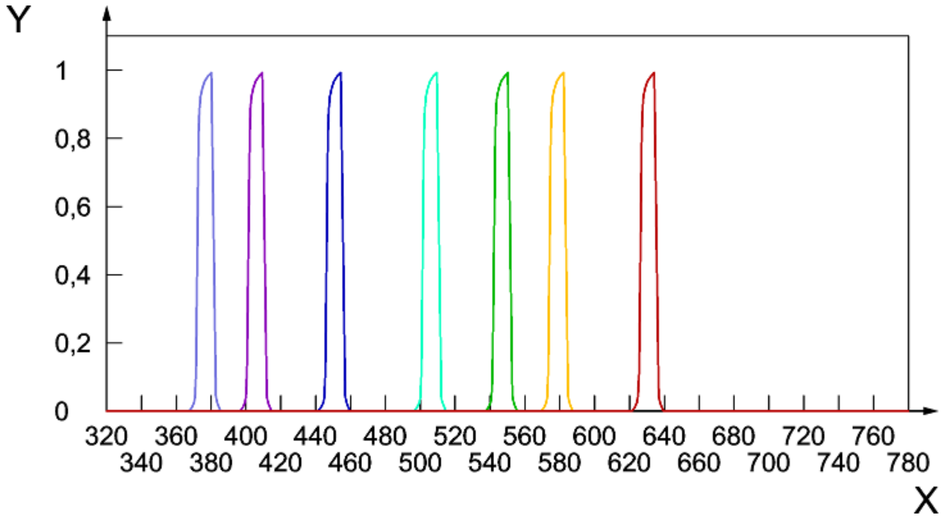


Key

— N-WG320
— GG395
— GG420
— GG435
— GG455
— GG495
— OG515
— OG530
— OG550
— OG570
— OG590
— RG610
— RG630
X wavelength [nm]
Y intensity [a.u.]

Figure A.1 — Examples for Cut-On-filters (see [13])

A.3 Examples for available band-pass-filters



Key

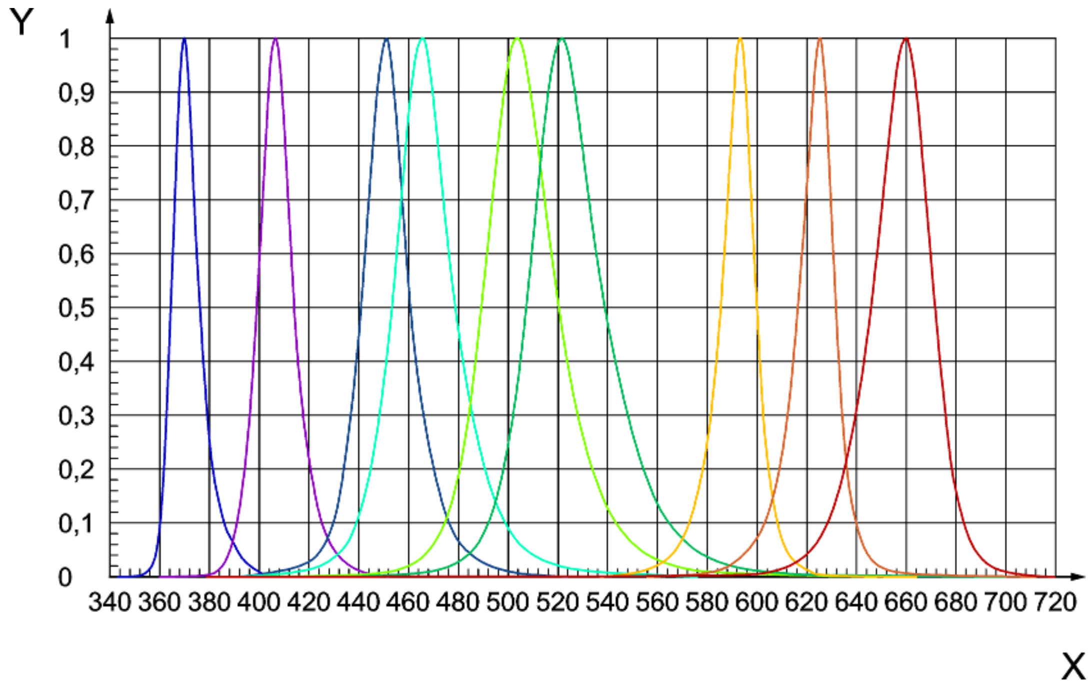
— XCC376-8
— XCC405-8
— XCC450-8
— XCC505-8
— XCC546-8
— XCC578-8
— XCC630-8
X wavelength [nm]
Y intensity [a.u.]

Figure A.2 — Examples for Band-pass-filters (see [14])

Examples of available band-pass-filters:

- 376 nm (368 nm to 384 nm),
- 405 nm (397 nm to 413 nm),
- 450 nm (442 nm to 458 nm),
- 505 nm (497 nm to 513 nm),
- 546 nm (538 nm to 544 nm),
- 578 nm (570 nm to 586 nm),
- 630 nm (622 nm to 638 nm).

A.4 Examples for available light emitting diodes (LED)



Key

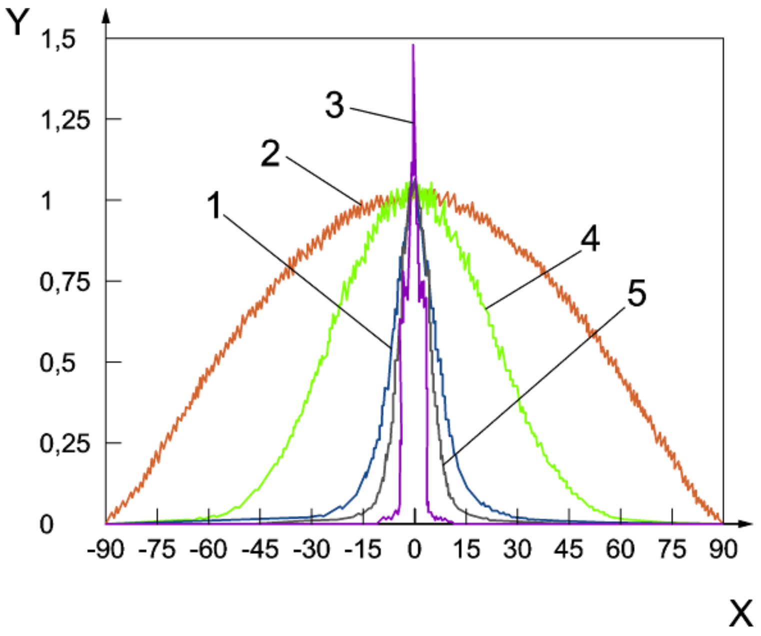
—	LEDMOD365	—	LEDMOD470	—	LEDMOD590	X	wavelengt [nm]
—	LEDMOD405	—	LEDMOD505	—	LEDMOD625	Y	intensity [a.u.]
—	LEDMOD455	—	LEDMOD528	—	LEDMOD640		

Figure A.3 — Examples for Light emitting diodes (LED) (see [15])

Examples for available wavelengths for different LEDs from PC-U to PC-R:

- 365 nm **(PC-U)**,
- 405 nm **(PC-V)**,
- 455 nm **(PC-B)**,
- 470 nm, 505 nm **(PC-C)**,
- 528 nm **(PC-G)**,
- 590 nm **(PC-A)**,
- 625 nm **(PC-R)** and 640 nm.

A.5 Example of different angle distribution of various diffusor types



Key

1	ground glass	5	holographic b (elliptical)
2	opal	X	angle in degrees
3	diffractive	Y	normalized intensity
4	holographic a (elliptical)		

Figure A.4 — Example for intensity distributions for various diffusers (see [16])

A.6 Examples for spectra of different fluorescence tubes

The top left image shows a spectrum of halogen lamp; all other spectra are from different types of fluorescence tubes.

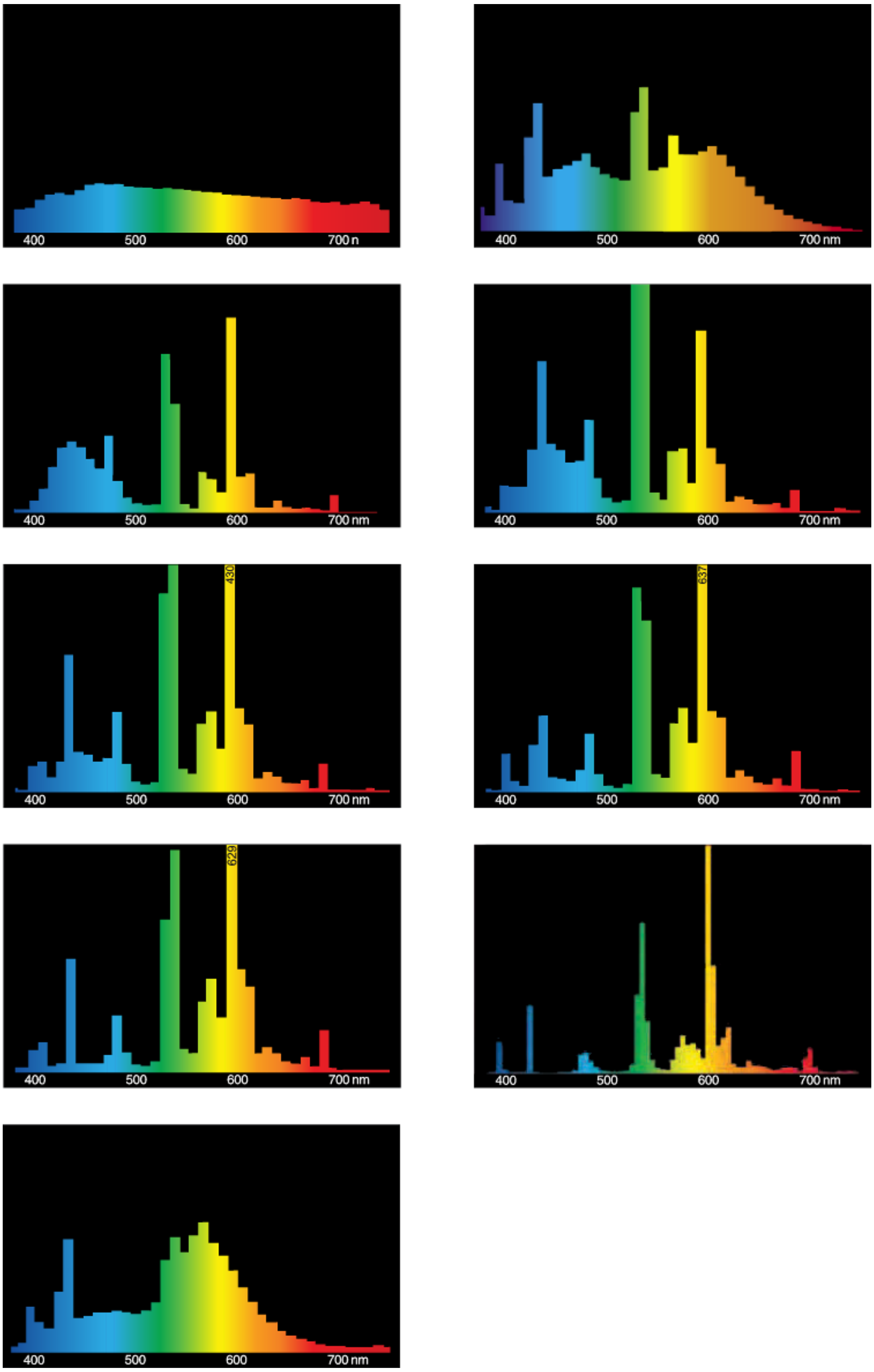


Figure A.5 — Example for spectra of different light sources (see [17])

Bibliography

[1] EN ISO 4892-1, *Plastics — Methods of exposure to laboratory light sources — Part 1: General guidance (ISO 4892-1)*

[2] EN ISO 4892-2, *Plastics — Methods of exposure to laboratory light sources — Part 2: Xenon-arc lamps (ISO 4892-2)*

[3] EN ISO 4892-3, *Plastics — Methods of exposure to laboratory light sources — Part 3: Fluorescent UV lamps (ISO 4892-3)*

[4] ISO 10677:2011, *Fine ceramics (advanced ceramics, advanced technical ceramics) — Ultraviolet light source for testing semiconducting photocatalytic materials*

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

[6] ISO 22197-1, *Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for air-purification performance of semiconducting photocatalytic materials — Part 1: Removal of nitric oxide*

[7] CIE S 017/E:2011, *International Lighting Vocabulary*

[8] CIE 85:1989, *Solar Spectral Irradiance*

[9] COLIPA Guidelines: *Guidelines for monitoring UV radiation sources*

[10] COLIPA, CTFA SA and JCIA International Sun protection factor (SPF) test method

[11] PURE APPL. *No. 12*. Chem. IUPAC, Vol. 76, 2004, pp. 2105–46.

[12] www.hamamatsu.com

[13] www.schott.de

[14] www.omegafilters.com

[15] www.omicron-laser.de

[16] www.thorlabs.de

[17] www.radium.de

This page deliberately left blank

This page deliberately left blank

British Standards Institution (BSI)

BSI is the national body responsible for preparing British Standards and other standards-related publications, information and services.

BSI is incorporated by Royal Charter. British Standards and other standardization products are published by BSI Standards Limited.

About us

We bring together business, industry, government, consumers, innovators and others to shape their combined experience and expertise into standards-based solutions.

The knowledge embodied in our standards has been carefully assembled in a dependable format and refined through our open consultation process. Organizations of all sizes and across all sectors choose standards to help them achieve their goals.

Information on standards

We can provide you with the knowledge that your organization needs to succeed. Find out more about British Standards by visiting our website at bsigroup.com/standards or contacting our Customer Services team or Knowledge Centre.

Buying standards

You can buy and download PDF versions of BSI publications, including British and adopted European and international standards, through our website at bsigroup.com/shop, where hard copies can also be purchased.

If you need international and foreign standards from other Standards Development Organizations, hard copies can be ordered from our Customer Services team.

Subscriptions

Our range of subscription services are designed to make using standards easier for you. For further information on our subscription products go to bsigroup.com/subscriptions.

With **British Standards Online (BSOL)** you'll have instant access to over 55,000 British and adopted European and international standards from your desktop. It's available 24/7 and is refreshed daily so you'll always be up to date.

You can keep in touch with standards developments and receive substantial discounts on the purchase price of standards, both in single copy and subscription format, by becoming a **BSI Subscribing Member**.

PLUS is an updating service exclusive to BSI Subscribing Members. You will automatically receive the latest hard copy of your standards when they're revised or replaced.

To find out more about becoming a BSI Subscribing Member and the benefits of membership, please visit bsigroup.com/shop.

With a **Multi-User Network Licence (MUNL)** you are able to host standards publications on your intranet. Licences can cover as few or as many users as you wish. With updates supplied as soon as they're available, you can be sure your documentation is current. For further information, email bsmusales@bsigroup.com.

Revisions

Our British Standards and other publications are updated by amendment or revision.

We continually improve the quality of our products and services to benefit your business. If you find an inaccuracy or ambiguity within a British Standard or other BSI publication please inform the Knowledge Centre.

Copyright

All the data, software and documentation set out in all British Standards and other BSI publications are the property of and copyrighted by BSI, or some person or entity that owns copyright in the information used (such as the international standardization bodies) and has formally licensed such information to BSI for commercial publication and use. Except as permitted under the Copyright, Designs and Patents Act 1988 no extract may be reproduced, stored in a retrieval system or transmitted in any form or by any means – electronic, photocopying, recording or otherwise – without prior written permission from BSI. Details and advice can be obtained from the Copyright & Licensing Department.

Useful Contacts:

Customer Services
Tel: +44 845 086 9001
Email (orders): orders@bsigroup.com
Email (enquiries): cservices@bsigroup.com

Subscriptions
Tel: +44 845 086 9001
Email: subscriptions@bsigroup.com

Knowledge Centre
Tel: +44 20 8996 7004
Email: knowledgecentre@bsigroup.com

Copyright & Licensing
Tel: +44 20 8996 7070
Email: copyright@bsigroup.com

BSI Group Headquarters

389 Chiswick High Road London W4 4AL UK

bsi.

...making excellence a habit.™