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Plastics — Methods of exposure to determine the wavelength dependent degradation using spectrally dispersed radiation

Plastiques — Méthodes d'exposition pour déterminer la dégradation dépendante de la longueur d'onde en utilisant un rayonnement dispersé spectralement

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Foreword

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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).

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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 61, *Plastics*, Subcommittee SC 6, *Ageing, chemical and environmental resistance*.

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.

Introduction

Plastics are used outdoors and indoors where they are exposed to solar radiation, to solar radiation filtered by window glass and to artificial radiation sources for long periods. Therefore, information on the wavelength dependent degradation of a polymer property (e.g. optical and mechanical) within the ultraviolet and visible solar spectrum is important. The results of this test determine the spectral sensitivity of a property change over the range of the ultraviolet and the visible solar spectrum.

Plastics — Methods of exposure to determine the wavelength dependent degradation using spectrally dispersed radiation

1 Scope

This document specifies methods of determining the spectral response of all kind of plastics materials to ultraviolet and visible radiation by an irradiation test with spectrally dispersed irradiation.

NOTE Typical specimens that are evaluated include: films, liquids, plaques, pellets, powders, sheets and discs.

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 291, *Plastics — Standard atmospheres for conditioning and testing*

ISO 472, *Plastics — Vocabulary*

ISO 4582, *Plastics — Determination of changes in colour and variations in properties after exposure to glass-filtered solar radiation, natural weathering or laboratory radiation sources*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 472 and the following 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
short-pass filter
filter that transmits wavelengths shorter than the cut-off wavelength while rejecting longer wavelengths, and characterized by a sharp transition from maximum to minimum transmittance

[SOURCE: ISO 9370:2017, 3.31]

3.2
long-pass filter
filter that transmits wavelengths longer than the cut-on wavelength while rejecting shorter wavelengths, and characterized by a sharp transition from minimum to maximum transmittance

[SOURCE: ISO 9370:2017, 3.21]

3.3
file specimens
portion of the material to be tested which is stored under conditions in which it is stable and which is used for comparison between the exposed and unexposed states

[SOURCE: ISO 4892-1:2016, 3.2]

3.4
action spectrum
description of the spectral efficiency of radiation to produce a particular polymer response (change in a specific property of a specific polymer) as a function of wavelength

Note 1 to entry: Data of an action spectrum are specific to the polymer but independent of the radiation source. This term is also known as spectral sensitivity.

3.5
reciprocal linear dispersion of the radiation
wavelength dispersion in the focal plane

Note 1 to entry: It is expressed in nm/mm.

3.6
spatial resolution of the exposure device
width of the image of the entrance slit in the specimen plane, to be calculated by the slit width multiplied by the reciprocal linear dispersion

3.7
spectral irradiance
E_λ
irradiance per wavelength interval

Note 1 to entry: It is typically reported in watts per square metre per nanometre ($W·m^{-2}·nm^{-1}$).

[SOURCE: ISO 9370:2017, 3.20]

3.8
spectral radiant exposure
time integral of *spectral irradiance* (3.7)

Note 1 to entry: It is expressed in joules per square metre per nanometre ($J·m^{-2}·nm^{-1}$).

4 Principle

A specimen is exposed to spectrally dispersed radiation. This exposure causes wavelength dependent degradation of a test specimen. The position of the degradation of a test specimen is a function of wavelength. Analysis of these parameters enables a quantitative evaluation of the degradation as a function of wavelength.

Additionally, the action spectrum can be quantified, by spatial measurement of both spectral irradiance and the resulting changes in the test specimen property.

Temperature control of the test specimen may be used.

NOTE General information on the test method is described in Annex A. Examples of devices for spectrally dispersed irradiation are shown in Annex B. Examples of test result are shown in Annex C.

5 Apparatus

5.1 Exposure device

The radiation source shall provide radiation covering the entire wavelength range under investigation, which is typically around 200 nm to 700 nm. If the light source generates ozone, the ozone shall be removed using an ozone treatment system.

NOTE 1 Typically, a Xenon arc lamp is used.

The radiation is directed to an entrance slit of an optical system. The width of the entrance slit determines the spectral resolution and the irradiance of spectrally dispersed radiation. A narrower entrance slit results in higher resolution and lower irradiance. Conversely, a wider entrance slit results in lower resolution and higher irradiance.

The radiation through the entrance slit is spectrally dispersed by means of a diffraction grating which should be widely illuminated. In order to optimize the deflection to get only one deflection order for a specific wavelength range, a blaze grating may be used.

For optical geometry, various imaging optical elements whose spectral characteristics should be optimized for ultraviolet and visible radiation can be used. An optical short-pass or long-pass filter should be used to exclude unwanted radiation such as stray radiation.

The image of the entrance slit shall be focused at a specimen mounting port. A specimen can be irradiated with radiation wavelengths separated along the horizontal axis of the specimen plane.

The range of wavelengths irradiating the specimen can be adjusted by moving or switching the angular position of the grating.

NOTE 2 For a simple check of the wavelength positions, interference filters can be used.

The width of the entrance slit and the design of the optical system dictates the spatial resolution. When determining the evaluation criteria of a property being examined, the spatial resolution should be considered.

Another relevant characteristic is the reciprocal linear dispersion of the radiation as wavelength range per specimen width (in nm/mm).

The height of the image in the specimen plane depends on the optical system design.

NOTE 3 As the lamp arc locally varies in temperature, the emitted spectral irradiance is not homogeneous over the arc height. By using a cylindrical mirror instead of a spherical one, height range as well as height homogeneity is increased, at the same time decreasing spectral irradiance/intensity.

Temperature control of the specimen under test may be used. Typically, the test is performed at ambient temperature. Other specimen temperatures may be used upon agreement with the interested parties and shall be reported. Because of the low irradiance of the dispersed radiation the radiation heating can be neglected.

Liquids, pellets and powder specimens are tested using a cell. Unless specified, this cell shall be made of clear, optically, transparent material (typically UV grade quartz).

5.2 Spectroradiometer

For measuring the spectral irradiance at various positions in the specimen plane, a spectroradiometer should be used. A calibrated diffusing detector with an entrance aperture diameter not greater than the spatial resolution of the exposure device enables the best characterization.

5.3 Measuring device for property change

For a quantitative evaluation, the property to be investigated shall be measured before and after the respective exposure. The lateral resolution of the measuring device should be adapted to the spatial resolution of the exposure device.

6 Test specimens

6.1 Specimen preparation and conditioning

The methods used for the preparation of test specimens can have a significant impact on test results.

The methods used for specimen preparation and conditioning should preferably be closely related to the methods used to qualify the material in its application. Therefore, the methods used for preparing and conditioning the specimen shall be agreed upon by the interested parties. A complete description of the methods used for preparing and conditioning the specimen shall be included in the test report.

6.2 Specimen conditioning

6.2.1 Condition test specimens in accordance with ISO 291, unless otherwise specified.

NOTE In case of photosensitive materials, storage in a dark and refrigerated environment can be advantageous.

6.2.2 When characterizing the optical and mechanical properties of the specimen, condition the specimen in accordance with ISO 291 before measurements. If the mechanical properties of the specimen are known to be sensitive to moisture content, the duration of conditioning may be longer than specified in ISO 291.

6.2.3 It is essential that colour measurement, visual evaluation of the specimen's colour and assessment of other optical properties be performed immediately after exposure. If conditioning the specimens in accordance with ISO 291 is desired before testing, the conditioning and the duration shall be based on agreement. The specimen conditioning shall be reported.

7 Exposure parameter

7.1 Radiation

Contact the manufacturer of the apparatus for specific spectral irradiance data, the reciprocal linear dispersion of the radiation and the spatial resolution. These parameters should be reported in the test report.

If necessary, measure the spectral irradiance at various positions, x, in the specimen plane. This measurement shall not be done during specimen exposure, as it should be performed in the exact specimen exposure height. Spectral irradiance integrals, $E_\lambda(\mathrm{x})$, as well as peak wavelengths, $\lambda(\mathrm{x})$ are related to the measured horizontal positions x in the specimen plane and should be presented as a table in the test report. As the spectral irradiance is averaged over the width of the irradiance detector, the detector's diameter is essential for this characterization.

NOTE 1 Minimum error and the highest precision are achieved when the detector width is less than the spatial resolution of the system.

If necessary, determine the reciprocal linear dispersion of the radiation as wavelength range per specimen width (in nm/mm). This can be done by relating the peak wavelengths of spectral irradiance measurements to the respective horizontal positions in the specimen plane.

NOTE 2 The spatial resolution is measured as FWHM of a spectral irradiance peak, using a detector that is smaller than the slit image in the specimen plane. Or it is calculated as the entrance slit width multiplied by the reciprocal linear dispersion.

During the exposure of the specimen, the irradiance should be controlled or checked.

NOTE 3 This is accomplished by continuous measurement at a specific wavelength in the specimen plane or by continuous measurement of the irradiance of the Xenon arc lamp.

7.2 Specimen temperature

Typically, the test is performed at standard atmosphere in accordance with ISO 291. Other specimen temperatures may be used upon agreement with the interested parties and shall be reported.

