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**Fine ceramics (advanced ceramics,  
advanced technical ceramics) —  
Measurement method of spectral  
reflectance of fine ceramic thin films  
under humid conditions**

*Céramiques techniques — Méthode de mesurage de la transmittance  
spectrale des films minces de céramiques fines en conditions humides*

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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](http://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](http://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](http://www.iso.org/iso/foreword.html).

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

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](http://www.iso.org/members.html).

## Introduction

Fine ceramic thin films are used in many optical applications, such as anti-reflective coatings, infrared sensor cut filters, X-ray sensor cut filters and band-pass filters. Even though the spectral reflectance of fine ceramic thin films is specified for each product, the refractive index and the optical properties change if these thin films are exposed to a humid environment. The reason for such changes in the optical properties is that water is adsorbed onto the surfaces inside the voids of fine ceramic thin films. A standard for evaluating the reliability of these films under a range of humidity conditions is therefore necessary. A standard for determining the spectral transmittance under humid and dry conditions was developed in ISO 17861. This document provides test methods that enable changes in the spectral reflectance of fine ceramic coatings in a humid environment due to water adsorption to be evaluated easily and accurately. The aim of this document is to promote the rapid adoption of this test method to facilitate further growth in this industry.

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# Fine ceramics (advanced ceramics, advanced technical ceramics) — Measurement method of spectral reflectance of fine ceramic thin films under humid conditions

## 1 Scope

This document specifies the procedure for measuring the spectral reflectance of fine ceramic thin films in an environment with variable relative humidity by using a general-purpose spectrophotometer.

## 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 8980-3, *Ophthalmic optics — Uncut finished spectacle lenses — Part 3: Transmittance specifications and test methods*

ISO 9211, *Optics and photonics — Optical coatings*

ISO 17861, *Fine ceramics (advanced ceramics, advanced technical ceramics) — Measurement method of spectral transmittance of fine ceramics thin films under humid condition*

## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 8980-3, ISO 9211 and ISO 17861 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

#### half of maximum/minimum reflectance wavelength

$\lambda_{R1/2}$   
wavelength at which the reflectance is equal to half of the maximum and minimum values observed in a spectral reflectance curve obtained for a certain range of wavelength

### 3.2

#### environmental mini-chamber

small chamber that is used to control humidity

Note 1 to entry: This chamber is equipped with a quartz window for the optical beam inlet and outlet, an evacuation feedthrough to evacuate the mini-chamber and an inlet to feed air with a controlled humidity to the mini-chamber.

### 3.3

#### spectral reflectance

regularly reflected or spectral component of the illumination (i.e. light that is reflected in a mirror-like way off a surface at the same angle and in the same plane as the incident ray) that is measured by using a spectral reflectometer

**3.4  
monochromator**

optical device that transmits a specific range of wavelengths from a polychromatic light

**3.5  
spectrophotometer**

optical instrument that measures spectral transmittance or reflectance

Note 1 to entry: This instrument consists of an optical source, a monochromator, a sample chamber, an optical detector, a signal processor, a data processor, and an interface

**3.6  
double-beam spectrophotometer**

type of spectrophotometer that is utilized to compare the light intensity of a reference sample with that of a test piece

Note 1 to entry: Compared with a single-beam spectrophotometer, this instrument provides a higher level of measurement stability. In a double-beam spectrophotometer, the energy of the source light beam is divided into two beams: a reference beam and a sample beam. The energy of the sample beam is detected by referring to the energy of the reference beam.

**3.7  
integrating sphere**

optical component consisting of a hollow spherical cavity with an inner surface that is covered with a diffuse white reflective coating

Note 1 to entry: The cavity is equipped with small holes for the mounting of a test piece and for the inlet and outlet of the light beam.

## 4 Principle

Fine ceramic thin films sometimes possess a voided micro columnar structure. Due to this structure, moisture in the air is adsorbed onto the surfaces of columns with voids between them. The quantity of adsorbed water is affected by the hydrostatic vapour pressure and temperature in the environment. Depending on the quantity of water that is adsorbed, the refractive index of a thin film changes, resulting in a change in its spectral reflectance. To evaluate what effects the adsorption of water on the surface of voids in fine ceramic thin films has on the spectral reflectance of thin films, it is necessary to measure the optical properties under a vacuum, a high-humidity environment and a low-humidity environment. Comparing the results measured under a vacuum, a high-humidity environment and a low-humidity environment facilitates an evaluation of changes in the spectral reflectance due to the environmental humidity.

## 5 Measurement room ambient environment

The tests shall be carried out in a measurement laboratory under a room atmosphere in which the temperature and humidity changes are negligible. In particular, to prevent the condensation of water in the environmental mini-chamber, the ambient temperature shall be controlled to restrict it to a certain range.

- a) Measurement room temperature:  $(23 \pm 2)$  °C.
- b) Measurement room relative humidity: below 70 %.

## 6 Test pieces

The test pieces shall comprise single-layer or multilayer thin films of fine ceramics deposited on substrates such as glass or polymer materials. There are no restrictions on the types of materials that can be used for the substrates, provided the measurements will not be disturbed by any of the

properties of the substrates. Any test piece is acceptable as long as it fits in the environmental mini-chamber in terms of its size and shape.

## 7 Measuring apparatus

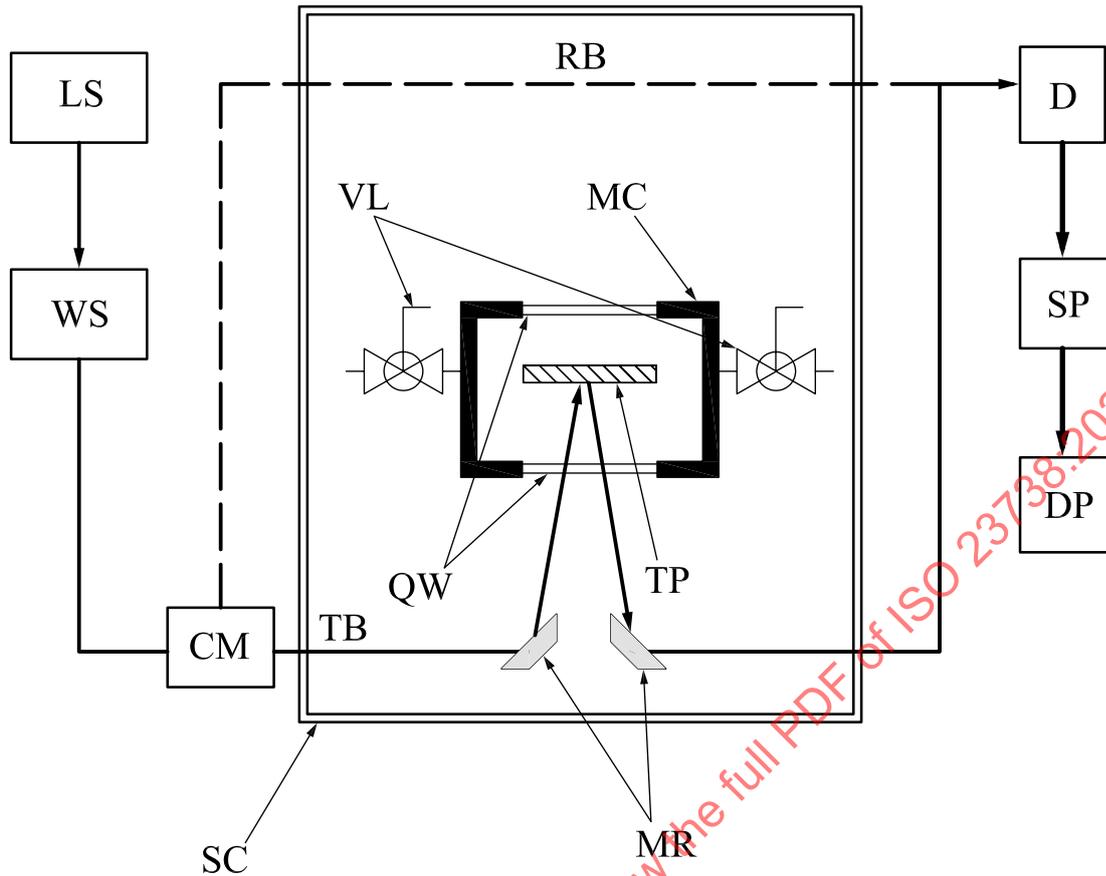
### 7.1 Apparatus configuration

- a) Spectrophotometer: an instrument that utilizes a double-beam method with a wavelength accuracy of  $\pm 0,2$  nm or less in UV-visible light and  $\pm 1,0$  nm or less in the near-infrared domain. The repeatability of the wavelength setting is  $\pm 0,1$  nm or less in UV-visible light and  $\pm 0,5$  nm or less in the near-infrared domain, with a desirable measurement range of 300 nm to 2 500 nm.

The use of a double-beam spectrophotometer is strongly recommended. However, the use of an integrating sphere is not mandatory.

- b) Environmental mini-chamber: an airtight container that maintains test pieces under a vacuum, a high-humidity environment and a low-humidity environment for the measurement of the spectral reflectance under each condition. The chamber consists of an optical feedthrough that comprises a transparent quartz glass plate, a backside window, and two valves for the inlet of environmental air and evacuation. A test piece is fixed inside the chamber for the measurement of light reflectance. It is necessary to confirm that there is no vacuum leak from the chamber when the valves are closed.

The spectrometry device configuration is shown in [Figure 1](#). An example of the blueprint is shown in [Annex A](#).



**Key**

- |    |                                     |    |                  |
|----|-------------------------------------|----|------------------|
| LS | light source                        | VL | valves           |
| WS | wavelength selector (monochromator) | QW | quartz window    |
| CM | chopper mirror                      | MR | mirrors          |
| SC | specimen compartment                | D  | detector         |
| MC | environmental mini-chamber          | SP | signal processor |
| TB | test beam                           | DP | data processor   |
| RB | reference beam                      | TP | test piece       |

**Figure 1 — Device configuration for spectral reflectance measurements**

- c) Vacuum evacuation: an exhaust equipment rotary pump or a dry pump shall be used. Any type can be used, provided the ultimate pressure is less than 40 Pa.
- d) Temperature/humidity-controlled chamber: a type of chamber that allows the temperature and relative humidity to be set to 23 °C and from 40 % to 80 %, respectively. It is desirable to measure the humidity around the test pieces by using a hygrometer.

**7.2 Spectrophotometer calibration**

Perform a wavelength and reflectance calibration for the spectrophotometer apparatus as follows:

- a) Wavelength calibration: apply a test method that uses an optical glass filter.
- b) Baseline correction: set the spectral reflectance to 100 % within the range of the measuring wavelength by using the baseline adjustment function of the apparatus without setting an environmental mini-chamber.

## 8 Environmental conditions and control procedures

Expose the test piece to the required environmental conditions before measuring the spectral reflectance. The test piece should not be removed from the environmental mini-chamber during the series of measurements conducted under a vacuum, a high-humidity environment and a low-humidity environment. The recommended measurement conditions for a vacuum, a high-humidity environment and a low-humidity environment are as follows.

- a) Vacuum: evacuate the environmental mini-chamber containing the test piece by connecting one of its valves to a vacuum pump. Evacuate for more than 30 min.
- b) High-humidity environment: place the environmental mini-chamber containing a test piece in the temperature/humidity-controlled chamber. Open both of the valves and expose the test piece to the required temperature and humidity conditions. The temperature and relative humidity of the temperature/humidity-controlled chamber are  $(23 \pm 2)$  °C and  $(80 \pm 2)$  %, respectively. The recommended retention time is 20 min.
- c) Low-humidity environment: place the environmental mini-chamber containing a test piece in the temperature/humidity-controlled chamber. Open both of the valves and expose the test piece to the required temperature and humidity conditions. The temperature and relative humidity of the temperature/humidity-controlled chamber are  $(23 \pm 2)$  °C and  $(40 \pm 2)$  %, respectively. The recommended retention time is 20 min.

## 9 Reflectance measurement procedure

Measure the spectral reflectance within the required wavelength range. For a wavelength range that is shorter than 850 nm, use the following conditions: a wavelength interval of 0,2 nm, a scanning speed below 120 nm/min, a fast response and a light incident angle of 5° to the test piece. For a wavelength range that is longer than 850 nm, use the following conditions: a wavelength interval of 0,2 nm, a scanning speed below 150 nm/min, a fast response and a light incident angle of 5° to the test piece.

- a) Measurement position: measure the spectral reflectance at the centre of the test piece. An optical diaphragm is not required if the dimensions of the test piece are larger than the window diameter of the environmental mini-chamber.
- b) Measurement of reflectance under a vacuum: measure the reflectance under a vacuum after finishing the evacuation procedure.
- c) Measurement of reflectance under a high-humidity environment: measure the reflectance under the required humidity conditions after exposing the test piece to the required conditions in a temperature/humidity-controlled chamber. The recommended temperature and relative humidity are  $(23 \pm 2)$  °C and  $(80 \pm 2)$  %, respectively.
- d) Measurement of reflectance under a low-humidity environment: measure the reflectance under the required humidity conditions after exposing the test piece to the required conditions in a temperature/humidity-controlled chamber. The recommended temperature and relative humidity are  $(23 \pm 2)$  °C and  $(40 \pm 2)$  %, respectively.

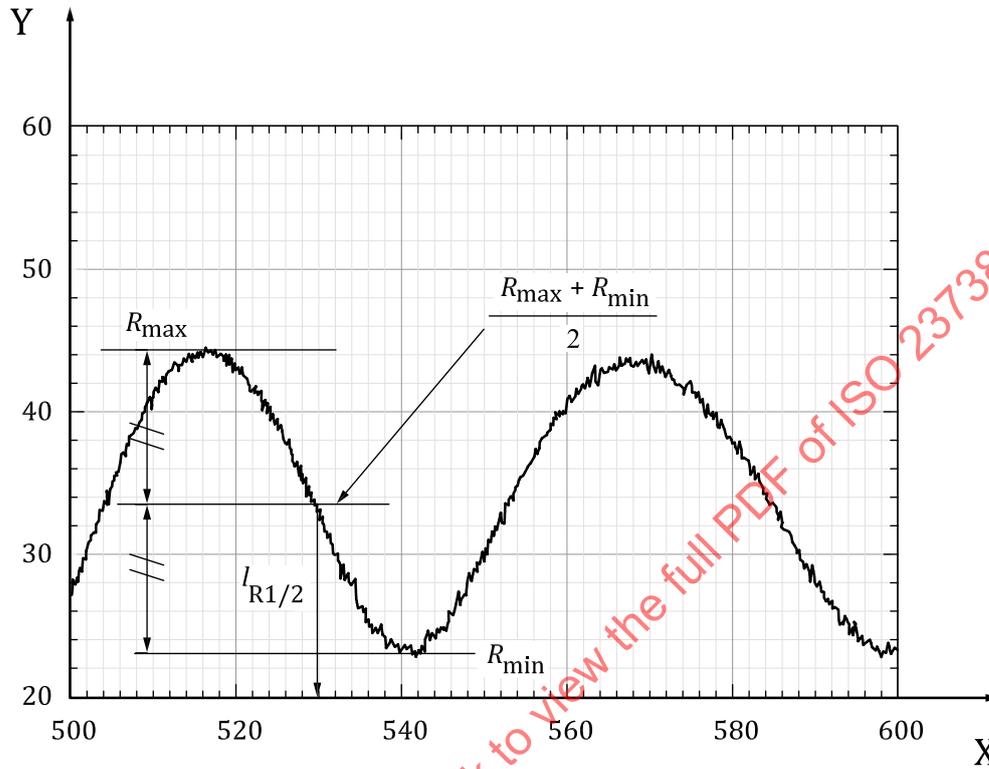
## 10 Evaluations of spectral shifts between dry and humid conditions

### 10.1 General

Evaluate changes in the spectral reflectance of fine ceramic thin films. The evaluation methods used for several typical types of changes observed in the spectra are shown in this clause. The evaluation method should be optimized to obtain appropriate results for evaluating the film optical properties based on the applications.

### 10.2 Single-layer films

Obtain the half of maximum/minimum reflectance wavelength,  $\lambda_{R1/2}$ , from the spectral reflectance spectra measured under a vacuum, a high-humidity environment and a low-humidity environment from the spectral reflectance measured as shown in [Figure 2](#). After that, evaluate the shift for  $\lambda_{R1/2}$  vacuum, high-humidity and low-humidity conditions.

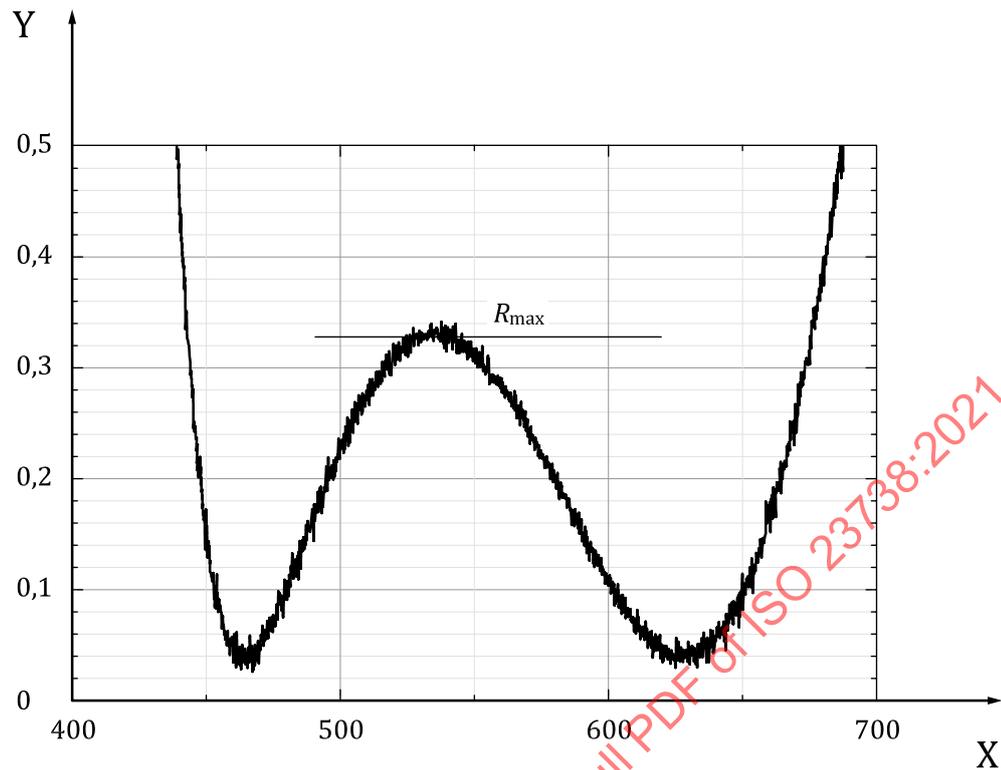


**Key**  
 X wavelength (nm)  
 Y reflectance (%)

**Figure 2 — Half of maximum/minimum reflectance wavelength,  $\lambda_{R1/2}$ , obtained for a single-layer film**

### 10.3 Anti-reflective coatings

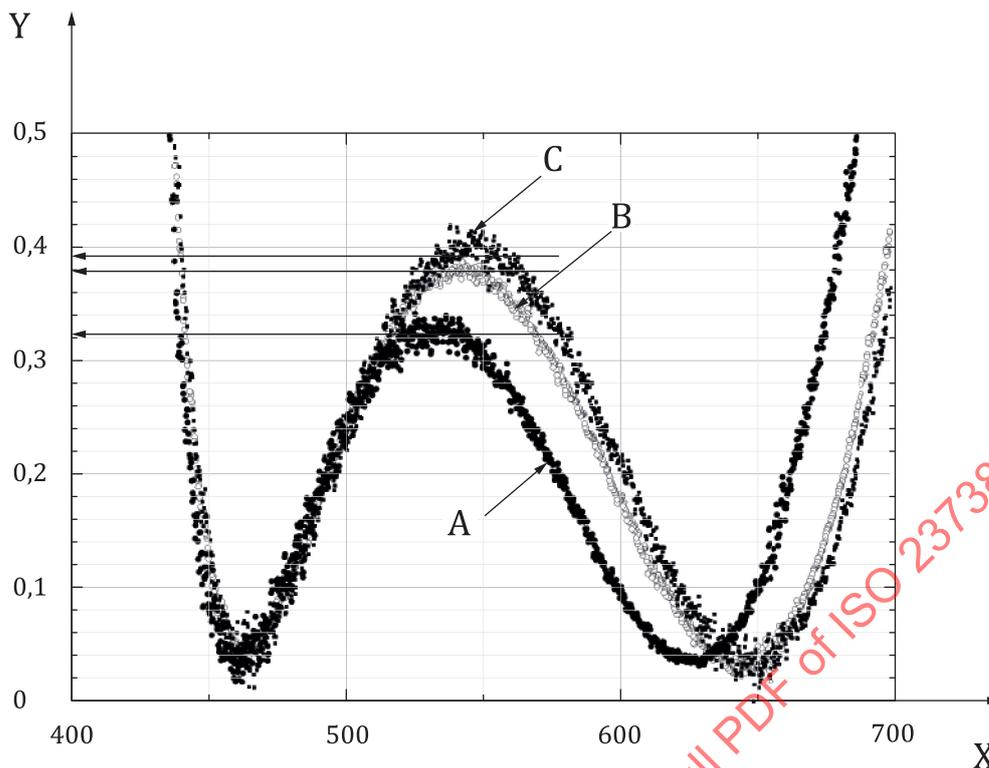
Obtain the maximum reflectance value from the spectral reflectance spectra measured under a vacuum, a high-humidity environment and a low-humidity environment, as shown in [Figure 3](#). After that, evaluate changes in the maximum reflectance under a vacuum, a high-humidity environment and a low-humidity environment, as shown in [Figure 4](#).

**Key**

X wavelength (mm)

Y reflectance (%)

Figure 3 — Maximum reflectance spectra,  $R_{\max}$ , obtained for an anti-reflective coating



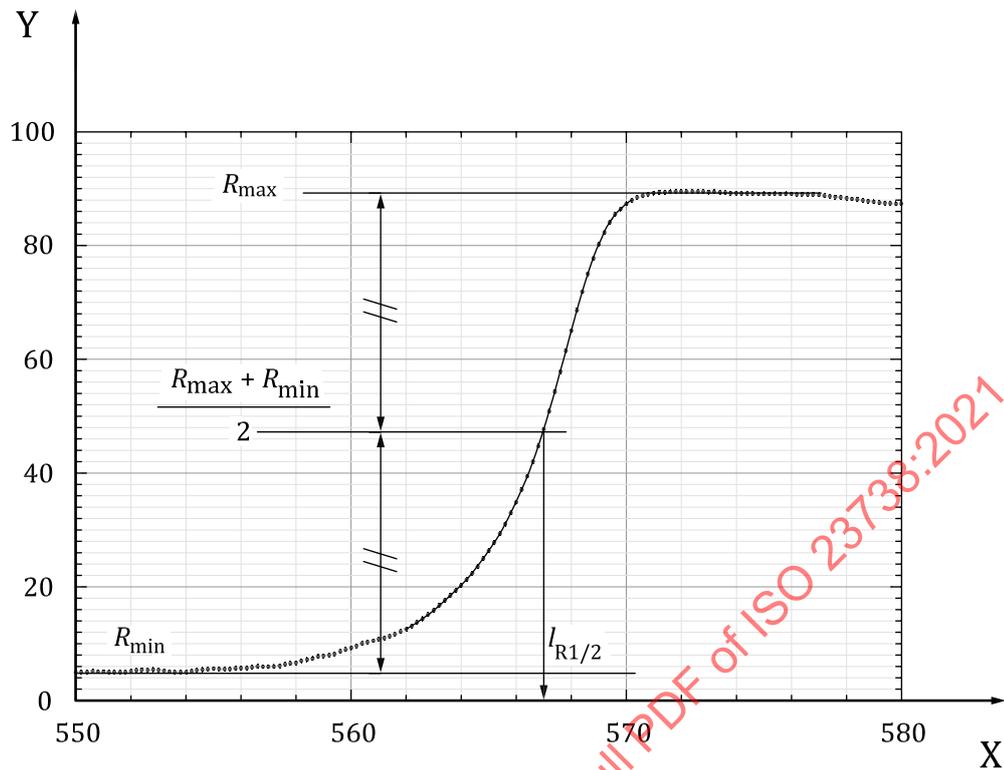
**Key**

- X wavelength (mm)
- Y reflectance (%)
- A vacuum
- B RH (relative humidity) 40 %
- C RH 80 %

**Figure 4 — Example of shifts in the maximum reflectance spectra,  $R_{max}$ , evaluated for an anti-reflective coating**

**10.4 Edge filters**

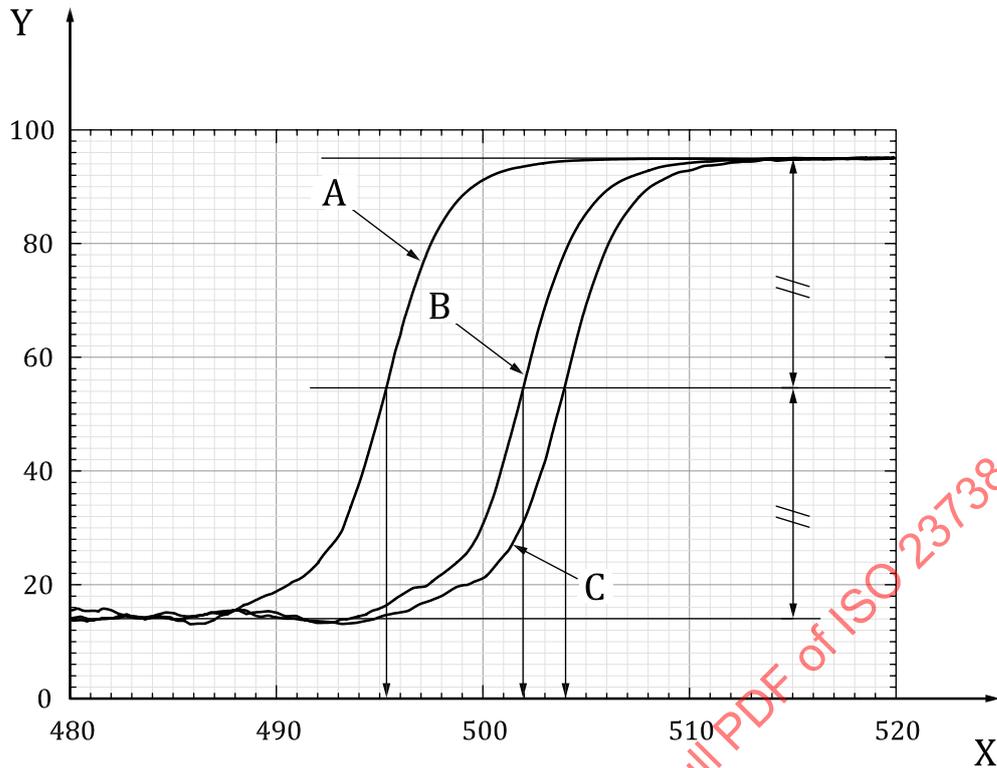
Obtain the half of maximum/minimum reflectance wavelength at the edge wavelength,  $\lambda_{R1/2}$ , from the reflectance spectra measured under a vacuum, a high-humidity environment and a low-humidity environment, as shown in [Figure 5](#). After that, evaluate changes in the half of maximum/minimum reflectance wavelength,  $\lambda_{R1/2}$ , under a vacuum, a high-humidity environment and a low-humidity environment, as shown in [Figure 6](#).

**Key**

X wavelength (nm)

Y reflectance (%)

**Figure 5 — Half of maximum/minimum reflectance wavelength,  $\lambda_{R1/2}$ , obtained for an edge filter**



**Key**

- X wavelength (nm)
- Y reflectance (%)
- A vacuum
- B RH 40 %
- C RH 80 %.

**Figure 6 — Example of shifts in the half of maximum/minimum reflectance wavelength,  $\lambda_{R1/2}$ , evaluated for an edge filter**

**11 Test report**

The test report shall include the following:

- a) Reference to this document (i.e. determined in accordance with ISO 23738).
- b) Test date, name of the testing establishment, temperature and relative humidity.
- c) Description of the test piece and its identity.
- d) Description of the measuring apparatus.
- e) Description of the test conditions, the vacuum evacuation time, the temperature and relative humidity of the temperature/humidity-controlled chamber, and the exposure time for the high- and low-humidity environments. In addition, the duration of time since the evacuation was finished or since the test piece was withdrawn from the temperature/humidity-controlled chamber.
- f) Description of measured data. In addition, if an optical glass filter is used for the wavelength calibration, the manufacturer and type as well as the distribution curve and reflectance value of the spectral reflectance. The spectral reflectance of the test pieces that was obtained under a vacuum, a high-humidity environment and a low-humidity environment. Any property shift data obtained under a vacuum, a high-humidity environment and a low-humidity environment.

g) Special instructions regarding measurements.

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