INTERNATIONAL STANDARD

ISO 9211-2

Second edition
2010-03-15

Optics and photonics — Optical coatings —

Part 2: Optical properties

Optique et photonique — Traitements optiques —

Partie 2: Propriétés optiques

Reference number
ISO 9211-2:2010(E)

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 9211-2 was prepared by Technical Committee ISO/TC 172, *Optics and photonics*, Subcommittee SC 3, *Optical materials and components*.

This second edition cancels and replaces the first edition (ISO 9211-2:1994) which has been technically revised.

ISO 9211 consists of the following parts, under the general title *Optics and photonics — Optical coatings*:

— *Part 1: Definitions*

— *Part 2: Optical properties*

— *Part 3: Environmental durability*

— *Part 4: Specific test methods*

Optics and photonics — Optical coatings —

Part 2: Optical properties

1 Scope

ISO 9211 identifies surface treatments of components and substrates excluding ophthalmic optics (spectacles) by the application of optical coatings and gives a standard form for their specification. It defines the general characteristics and the test and measurement methods whenever necessary, but is not intended to define the process method.

This part of ISO 9211 indicates how to specify optical properties of coatings and to represent their spectral characterization graphically.

2 Normative references

The following referenced documents are indispensable for the application 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 9211-1, *Optics and photonics — Optical coatings — Part 1: Definitions*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 9211-1 apply.

4 Optical properties to be specified

When specifying optical properties, the refractive indices of the incidence medium and the emergent medium shall be given. The polarization state of the incident radiation shall also be indicated if the angle of incidence, θ, is different from zero or a range of angles of incidence is given. If there is no indication, unpolarized radiation is assumed.

The optical properties $\tau(\lambda)$, $\rho(\lambda)$, $\alpha(\lambda)$, $D(\lambda)$ and $\Delta\Phi(\lambda)$ of a coating shall be specified by using the formulation given and explained in 6.2 in order to provide a comprehensive description of a coating with regard to its minimum set of optical properties. Other optical properties like scattering or colorimetric parameters etc. shall be subject to agreement between supplier and user if appropriate.

5 Measurement conditions

The measurement conditions for the spectrophotometric characterization shall be subject to agreement between supplier and user. These conditions depend on the principle of the measurement method and the instruments used, including the angle of incidence, the state of polarization, the spectral range and bandwidth of the measurement beam, etc. and shall be recorded in sufficient detail to enable verification of the measurement.

6 Numerical specification and graphical representation of spectral characteristics

6.1 General

This part of ISO 9211 defines the rules for the spectrophotometric characterization of optical coatings.

6.2 Rules for the numerical specification of spectral characteristics

The general structure of a numerical specification, as distinguished from a graphical specification, of a spectral optical property shall follow the structure of an inequality with the following terms:

(lower limit term) $<$ or $\leqslant$ (spectral optical property term) $<$ or $\leqslant$ (upper limit term).

EXAMPLE 1 (lower limit term) $<$ (spectral optical property term) $\leqslant$ (upper limit term).

The inequality may contain only two terms if the spectral optical property needs to be bounded only on one side.

EXAMPLE 2 (spectral optical property term) $\leqslant$ (upper limit term) or (spectral optical property term) $>$ (lower limit term).

Table 1 gives a schematic representation of elements necessary for the numerical specification of spectral characteristics as shown in Table 2.

NOTE Unless otherwise specified, the symbols τ and ρ denote the specular transmittance and reflectance.

Table 1 — Scheme of elements for the numerical specification of spectral characteristics

Lower limit (subscript L) i = 1, 2, ...	**Comparator sign**	**Spectral optical property**	**Wavelength (or wavenumber) range or single wavelength (or wavenumber), angle of incidence**[a] i = 1, 2, ...	**Comparator sign**	**Upper limit** (subscript U) i = 1, 2, ...	Z **represents any of**
$Z_{\mathrm{L}i}$	$<$ or $\leqslant$	Z	(λ_i to λ_{i+1}, θ) or (λ_i, θ)	$<$ or $\leqslant$	$Z_{\mathrm{U}i}$	τ, ρ, α, D, $\Delta\Phi$ or $\delta\Phi$
$Z_{\mathrm{L}i} \rightarrow Z_{\mathrm{L}i+1}$[b]	$<$ or $\leqslant$	Z	(λ_i to λ_{i+1}, θ)	$<$ or $\leqslant$	$Z_{\mathrm{U}i} \rightarrow Z_{\mathrm{U}i+1}$[b]	τ, ρ, α, D, $\Delta\Phi$ or $\delta\Phi$
$Z_{\mathrm{ave,L}i}$	$<$ or $\leqslant$	Z_{ave}	(λ_i to λ_{i+1}, θ)	$<$ or $\leqslant$	$Z_{\mathrm{ave,U}i}$	τ, ρ, α, D, or $\Delta\Phi$ or $\delta\Phi$
$Z_{\mathrm{s,L}i}$	$<$ or $\leqslant$	Z_{s}	(λ_i to λ_{i+1}, θ) or (λ_i, θ)	$<$ or $\leqslant$	$Z_{\mathrm{s,U}i}$	τ, ρ, α, or D
$Z_{\mathrm{s,ave,L}i}$	$<$ or $\leqslant$	$Z_{\mathrm{s,ave}}$	(λ_i to λ_{i+1}, θ)	$<$ or $\leqslant$	$Z_{\mathrm{s,ave,U}i}$	τ, ρ, α, or D
$Z_{\mathrm{p,L}i}$	$<$ or $\leqslant$	Z_{p}	(λ_i to λ_{i+1}, θ) or (λ_i, θ)	$<$ or $\leqslant$	$Z_{\mathrm{p,U}i}$	τ, ρ, α, or D
$Z_{\mathrm{p,ave,L}i}$	$<$ or $\leqslant$	$Z_{\mathrm{p,ave}}$	(λ_i to λ_{i+1}, θ)	$<$ or $\leqslant$	$Z_{\mathrm{p,ave,U}i}$	τ, ρ, α, or D

[a] Each optical property can be specified for different wavelength (or wavenumber) ranges and/or different single wavelengths (or wavenumbers), if necessary.

If the angle of incidence θ is not explicitly indicated, an angle of 0° is assumed.

For special applications, a range of angles of incidence (θ_1 to θ_2) instead of a single angle can be specified.

If the angle of incidence θ is different from 0° or a range of angles is given, but neither s- nor p-polarization is defined, the radiation is assumed to be unpolarized.

[b] The arrow $\rightarrow$ indicates a linear change of the tolerance limit from value $Z_{\mathrm{L}i}$ at λ_i to value $Z_{\mathrm{L}i+1}$ at λ_{i+1} (from value $Z_{\mathrm{U}i}$ at λ_i to value $Z_{\mathrm{U}i+1}$ at λ_{i+1}, respectively).

Table 2 — Numerical examples

Code designation[a]	Spectral characteristics (numerical specification)
AB	0,75 $\rightarrow$ 0,60 < α (500 nm to 600 nm) < 0,90 $\rightarrow$ 0,75
RE	ρ (400 nm to 700 nm) > 0,98 ρ_{ave} (400 nm to 700 nm) $\geqslant$ 0,995
FI-BP	0,85 $\leqslant$ τ (535 nm to 565 nm) $\leqslant$ 0,95 τ (400 nm to 515 nm) < 0,05 τ (585 nm to 720 nm) < 0,15
PC	89° $\leqslant$ $\Delta\Phi$ (10,6 µm, 45°) $\leqslant$ 91° ρ (10,6 µm, 45°) > 0,97
PO	ρ_s (450 nm to 650 nm, 45°) > 0,95 ρ_p (450 nm to 650 nm, 45°) < 0,05

[a] The code designations are given in ISO 9211-1:2010, Table 1.

6.3 Rules for the graphical representation of spectral characteristics

6.3.1 Spectrophotometric characterization consists of indicating the following in a graph:

a) on the abscissa, the spectral region in which the characteristics are specified as a function of wavelength, λ, in nanometres or micrometres, or wavenumber, σ, in reciprocal centimetres;

b) on the ordinate, the values of the individual optical properties (τ, ρ, α, D or $\Delta\Phi$).

6.3.2 The upper and/or lower tolerance limits (indicated by subscripts U and L respectively) within which the spectral characteristics must be located shall be indicated on the graph with hatched areas outside of the tolerance band. An alternative is the marking with triangles (▲ for the lower tolerance limit and ▼ for the upper tolerance limit) at both edges of the corresponding tolerance band. This way of marking is especially suited for tolerance limits at defined single wavelengths. If average values are specified, this shall be indicated as text on the graph, e.g. $\tau_{ave,L} < \tau_{ave} (\lambda_1 \text{ to } \lambda_2) < \tau_{ave,U}$.

6.3.3 If the coating is employed in several spectral regions, the characterization of the function in those different regions may appear on the same representation. Using different scales is permitted if necessary.

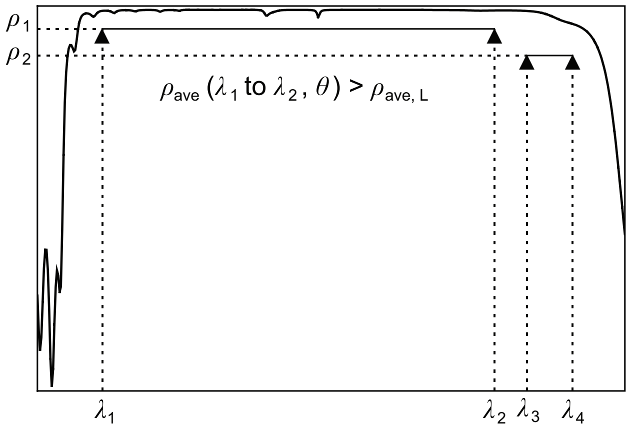
6.4 Graphical representation of principal optical functions

6.4.1 General

The following graphical representations of principal optical functions shall be used for specification and actual measurement. If appropriate, specified and measured upper, lower and/or average values can be combined in one graphical representation. The curves, the limits, and the numerical values shown in the following figures are only examples used for illustration. They shall not be taken as typical or standard values and limits.

6.4.2 Reflecting function (RE)

The reflecting function shall be characterized by its lower tolerance limit, ρ_L, of spectral reflectance. The upper tolerance limit, ρ_U, should also be indicated if necessary.



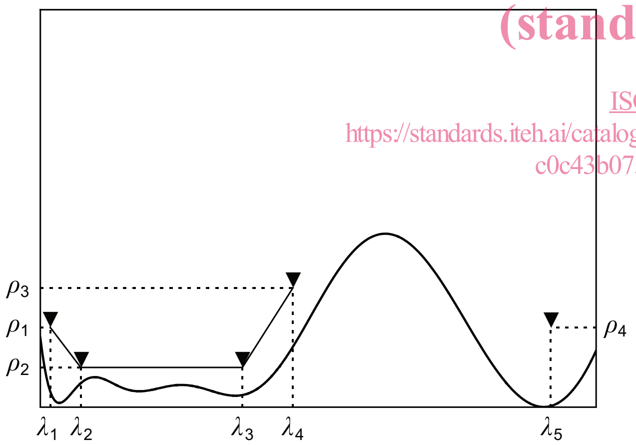
General designation:
RE $\rho\,(\lambda_{2i-1}$ to $\lambda_{2i}, \theta) > \rho_i$, …; $i = 1, 2, \ldots$

Numerical example:
RE ρ (400 nm to 700 nm, 25° to 35°) > 0,98
ρ (730 nm to 770 nm, 25° to 35°) > 0,96
ρ_{ave} (400 nm to 700 nm, 25° to 35°) > 0,995

Figure 1 — Reflecting function

6.4.3 Antireflecting function (AR)

The antireflecting function shall be characterized by its upper tolerance limit of spectral reflectance, ρ_U. If necessary, the spectral transmittance with its lower tolerance limit, τ_L, should be indicated.



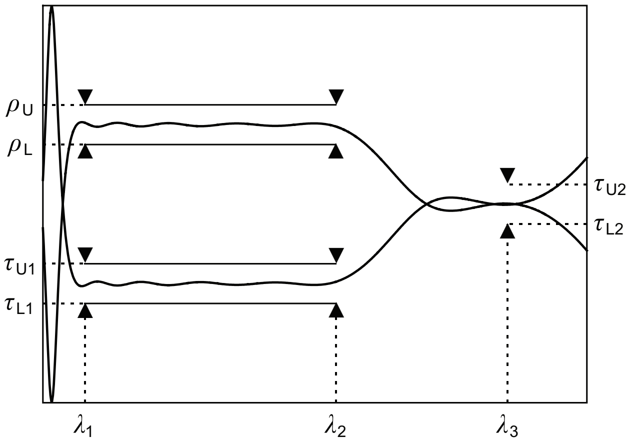
General designation:
AR $\rho\,(\lambda_i$ to $\lambda_{i+1}, \theta) < \rho_i\,[\rightarrow \rho_{i+1}]$, …; $i = 1, 2, \ldots$

Numerical example:
AR ρ (410 nm to 420 nm, 0° to 30°) < 0,01 → 0,005
ρ (420 nm to 600 nm, 0° to 30°) < 0,005
ρ (600 nm to 640 nm, 0° to 30°) < 0,005 → 0,015
ρ (905 nm, 0° to 30°) < 0,01

Figure 2 — Antireflecting function

6.4.4 Beam splitting function (BS)

The beam splitting function shall be characterized by its upper and lower tolerance limits (τ_U, τ_L, ρ_U, ρ_L) of spectral transmittance and spectral reflectance. These two representations may be shown in separate graphs.



General designation:

BS $\tau_{Li} < \tau(\lambda_{2i-1}$ to $\lambda_{2i}, \theta) < \tau_{Ui}, \ldots,$

$\rho_{Li} < \rho(\lambda_{2i-1}$ to $\lambda_{2i}, \theta) < \rho_{Ui}, \ldots;$ $i = 1, 2, \ldots$

Numerical example:

BS $0{,}25 < \tau$ (400 nm to 700 nm, 40° to 50°) $< 0{,}35$

$0{,}45 < \tau$ (905 nm, 40° to 50°) $< 0{,}55$

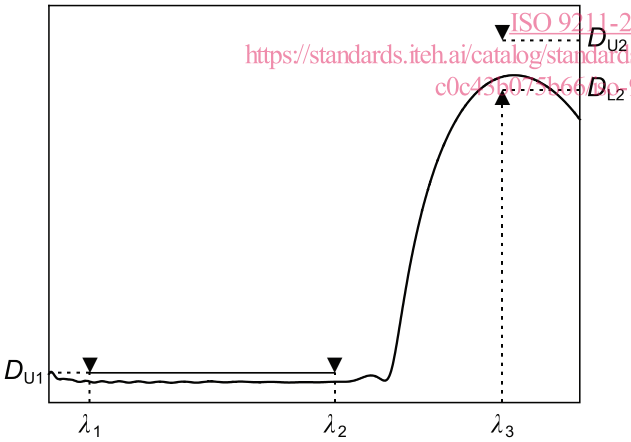
$0{,}65 < \rho$ (400 nm to 700 nm, 40° to 50°) $< 0{,}75$

Figure 3 — Beam splitting function

6.4.5 Attenuating function (AT)

The attenuating function shall be characterized by its upper and lower tolerance limits (τ_U, τ_L) of spectral transmittance or spectral optical density (D_U, D_L).

NOTE Spectral optical density is related to spectral transmittance by the formula $D(\lambda) = -\log \tau(\lambda)$.



General designation:

AT $D_{Li} < D(\lambda_{2i-1}$ to $\lambda_{2i}, \theta) < D_{Ui}, \ldots;$ $i = 1, 2, \ldots$

Numerical example:

AT D (400 nm to 700 nm, 5°) $< 0{,}1$

$3{,}0 < D$ (905 nm, 5°) $< 3{,}5$

Figure 4 — Attenuating function

