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ISO 9211-1

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Optics and optical instruments — Optical coatings —

Part 1:
Definitions

Optique et instruments d'optique — Traitements optiques —
Partie 1: Définitions

Reference number
ISO 9211-1:1994(E)

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.

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.

International Standard ISO 9211-1 was prepared by Technical Committee ISO/TC 172, *Optics and optical instruments*, Subcommittee SC 3, *Optical materials and components*.

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

— *Part 1: Definitions*

— *Part 2: Optical properties*

— *Part 3: Environmental durability*

— *Part 4: Specific test methods*

Annex A of this part of ISO 9211 is for information only.

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Optics and optical instruments — Optical coatings —

Part 1:
Definitions

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 defines terms relevant to optical coatings. These terms are grouped in four classes, basic definitions, definition of coatings by function, definitions of common coating imperfections and other definitions.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 9211. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 9211 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 31-6:1992, *Quantities and units — Part 6: Light and related electromagnetic radiations.*

ISO 6286:1982, *Molecular absorption spectrometry — Vocabulary — General — Apparatus.*

ISO 9211-4:—[1], *Optics and optical instruments — Optical coatings — Part 4: Specific test methods.*

ISO 10110-7:—[1], *Optics and optical instruments — Preparation of drawings for optical elements and systems — Part 7: Surface imperfection tolerances.*

ISO 10110-8:—[1], *Optics and optical instruments — Preparation of drawings for optical elements and systems — Part 8: Surface texture.*

IEC 50(845):1987, *International Electrotechnical Vocabulary — Chapter 845: Lighting.*

CIE Publication 38:1977, *Radiometric and photometric characteristics of materials and their measurements.*

1) To be published.

3 Basic definitions

3.1 Surface treatment

3.1.1 surface treatment of components and substrates: Application of a "coating" of material intended to modify the optical, physical or chemical characteristics originally possessed by the surface of a component. An optical component carrying such coating is also termed "substrate".

The substrates are considered to be geometrically perfect and optically homogeneous. In reality, an assembly made up of a substrate and a surface treatment is identified and measured experimentally as an entity.

The direction of the electromagnetic radiation transmitted and reflected by a coated surface is given by the incident medium and the emergent medium.

3.1.2 incident medium: Medium from which the electromagnetic radiation enters the coating.

3.1.3 emergent medium: Medium into which the electromagnetic radiation exits the coating.

NOTE 1 The substrate carrying the coating physically can constitute the incident medium or the emergent medium, depending on the direction of propagation of the electromagnetic radiation through the media adjacent to the coating.

3.2 Optical properties of a coated surface

The optical properties of a coated surface are characterized by spectrophotometric values. These values relate to the radiant energy transported by electromagnetic waves (radiant or luminous) and they vary as a function of the wavelength, the angle of incidence, the state of polarization and the spatial redistribution (direction) of incident radiation by diffusion such as scatter.

NOTES

2 The wavelength (λ) can be replaced by the wavenumber (σ). The units recommended are the nanometre (nm) or the micrometre (µm) for the wavelength and the reciprocal centimetre for the wavenumber.

3 In French, values possessing the character of a spectral density in relation to the wavelength are denoted by adding the adjective "spectric" to the name of the inital value. They are represented by adding the subscript λ to the initial value symbol.

The adjective "spectral" is used to denote values which depend on wavelength but which do not possess the character of a spectral density. The functional dependency is generally indicated by writing (λ) in parentheses as part of the symbol. In English, the adjective "spectral" is used in both cases.

3.2.1 spectral transmittance, $\tau(\lambda)$ (see ISO 31-6 and ISO 6286)**:** Ratio of the spectral concentration of radiant or luminous flux transmitted, to that of the incident radiation.

NOTE 4 Spectral transmittance can be expressed in terms of optical density: $D(\lambda) = -\log \tau(\lambda)$.

3.2.2 spectral reflectance, $\rho(\lambda)$ (see ISO 31-6 and ISO 6286)**:** Ratio of the spectral concentration of radiant or luminous flux reflected, to that of the incident radiation.

3.2.3 spectral absorptance, $\alpha(\lambda)$ (see ISO 31-6 and ISO 6286)**:** Ratio of the spectral concentration of radiant or luminous flux absorbed, to that of the incident radiation.

NOTE 5 Spectral absorptance depends on the direction of propagation.

3.2.4 spectral scatter: Change of the spatial distribution of a beam of radiation when it is deviated or scattered in many directions by a surface or by a medium without change of frequency of the monochromatic components of which the radiation is composed.

NOTE 6 Definition as adopted for "diffusion" in the French version of IEC 50(845) and in CIE 38, see also ISO 10110-8.

The factors defined in 3.2.1 to 3.2.4 are interrelated as follows:

$$1 = \tau + \rho + \alpha$$

In this relationship

$$\tau = \tau_r + \tau_d$$

$$\rho = \rho_r + \rho_d$$

where

τ_r is the regular transmittance (specular);

ρ_r is the regular reflectance (specular);

τ_d is the diffuse transmittance;

ρ_d is the diffuse reflectance.

NOTE 7 If necessary, these values can be represented as an average over a wavelength range of $\lambda_2 - \lambda_1$ as follows:

$$\tau_{ave} = \frac{\int_{\lambda_1}^{\lambda_2} \tau(\lambda)\varepsilon(\lambda)\sigma(\lambda)\,d\lambda}{\int_{\lambda_1}^{\lambda_2} \varepsilon(\lambda)\sigma(\lambda)\,d\lambda}$$

where

$\varepsilon(\lambda)$ is the spectral emissivity (of the light source);

$\sigma(\lambda)$ is the spectral sensitivity (of the detector).

If $\varepsilon(\lambda)\sigma(\lambda)$ is the constant for spectrophotometric values, the average value can be calculated as:

$$\tau_{ave} = \frac{\int_{\lambda_1}^{\lambda_2} \tau(\lambda)\mathrm{d}\lambda}{\lambda_2 - \lambda_1} \approx \frac{\sum_{i=1}^{n} \tau(\lambda_i)\Delta\lambda}{\lambda_2 - \lambda_1}$$

where

$$\Delta\lambda = (\lambda_2 - \lambda_1)/n$$

3.2.5 refractive index, $n(\lambda)$: Ratio of the velocity of propagation of electromagnetic radiation in vacuum to the velocity of propagation of the electromagnetic radiation in a medium.

3.2.6 angle of incidence: Angle between the normal to the surface and the principal incident ray.

3.2.7 plane of incidence: Plane incorporating the normal to the surface and the principal incident ray.

3.3 Colorimetric parameters

A surface treatment for visual applications can be characterized by colorimetric parameters. These depend on the reference illumination source used and the optical properties of the treated surface.

3.4 Polarization

When a coating is used at an angle of incidence different from zero, its characteristics depend upon the state of polarization of the incident radiation and it may influence the polarization state of the emergent radiation. It may then be necessary to indicate the orientation of the electric field vector in relation to the plane of incidence.

3.4.1 linearly polarized radiation: Polarization where the orientation of the electric field vector remains constant.

Polarization S refers to the linear polarization where the electric field vector is perpendicular to the plane of incidence.

Polarization P refers to the linear polarization where the electric field vector is parallel to the plane of incidence.

3.4.2 elliptically polarized radiation: Polarization where the projection of the electric field vector onto a plane normal to the direction of propagation describes an ellipse.

3.4.3 circularly polarized radiation: Polarization where the projection of the electric field vector onto a plane normal to the direction of propagation describes a circle.

3.4.4 unpolarized radiation: Ordinary radiation which has been resolved into any pair of orthogonal electric field vectors with varied phase difference where the average magnitudes of the two orthogonal vectors are the same and their phase difference changes in a completely random fashion.

3.4.5 randomly polarized radiation: Polarization where the orientation of the electric field vector of linearly polarized radiation varies randomly with time.

3.5 Phase relations

3.5.1 Phase change

The electric field at a fixed point in space due to an electromagnetic wave can be described by a periodic function given by:

$$\boldsymbol{E} = A \cos\left(\frac{2\pi v t}{\lambda} - \Phi\right)$$

where

- $\boldsymbol{E}$ is the electric field vector;
- A is the amplitude;
- v is the velocity of propagation in the medium;
- t is the time;
- λ is the wavelength in the medium;
- Φ is the phase.

The angle $\Phi - \Phi_0$ represents the phase change between this wave and a reference wave with its electric field vector given by:

$$\boldsymbol{E}_0 = A \cos\left(\frac{2\pi v t}{\lambda} - \Phi_0\right)$$

3.5.2 Phase retardation and difference

Phase retardation is the result of phase change between the S and P components of the $\boldsymbol{E}$-field vector. The magnitude of this change is called the phase difference.

4 Definition of coatings by function

The coatings are defined according to their function, i.e. according to the nature of the principal modification to the surface properties that they realize.

Table 1 lists principal functions which can be realized by optical coatings at the current state of technology. The principal functions may be expanded in future to include novel developments.

A coating intended to realize a principal function as defined in table 1 can also include one or more secondary functions. Their relative importance with regard to the principal function should be indicated.

5 Definitions of common coating imperfections

5.1 Point-like imperfections

5.1.1 pinhole: Very small hole in the thin film.

5.1.2 spatter: Imperfections which result when small chunks of material fly from the hot crucible onto the substrate surface and adhere there, in evaporative coatings.

5.1.3 particle: Minute piece of matter on/in the thin film.

5.1.4 fine dust: Minute piece of matter on the surface of the thin film.

5.1.5 nodule: Small, knot-like imperfection on the surface.

5.2 Line-like imperfections

5.2.1 scratches: Marking or tearing of a surface that looks as though it had been done by either a sharp or rough instrument. Scratches occur on optical surfaces in all degrees from various accidental causes.

Table 1 — Definition of coatings by function

Function	Definition	Example of application
Reflecting	Coating increasing the reflectance of an optical surface over a specified wavelength range.	Mirrors
Antireflecting	Coating reducing the reflectance of an optical surface over a specified wavelength range and usually increasing the transmittance.	Limiting parasitic reflection
Beam splitting	Coating separating the incident flux into two beams, one transmitted and the other reflected, the energy distribution of each beam reproducing the incident energy distribution in essentially a non-selective manner, over a specified wavelength range.	Neutral beamsplitters Partial reflectors
Attenuating	Coating reducing the transmittance in essentially a non-selective manner over a specified wavelength range.	Neutral density filters
Filtering	Coating modifying the transmittance in a selective manner.	Filters
Selecting or combining	Coating dividing the incident radiation flux into two or more beams each one covering a limited spectral region and being propagated either by reflection or by transmission. The reverse path combines beams of different spectral regions.	Dichroic mirrors Beam combiners
Polarizing	Coating controlling the state of polarization of the emergent electromagnetic radiation, over a specified wavelength range.	Polarizers Non-polarizers
Phase changing	Coating controlling the phase change of the emergent electromagnetic radiation relative to the incident radiation, and/or the phase difference between S and P vectors, over a specified wavelength range.	Phase matching coatings Phase retarding coatings
Absorbing	Coating absorbing a specified value of the incident flux over a specified wavelength range.	Sunglasses Light traps
Supplementary function	Coating providing a non-optical property; this function is often combined with an optical function.	Electrical conduction Chemical or mechanical protection

5.2.2 hairline: Very fine, smooth scratch, usually straight.

5.2.3 crack: Fracture in the material of an optical element.

5.2.4 crazing: Small fractures in the coating layer.

5.2.5 sleek: Hairline scratch.

5.3 Area imperfections

NOTE 8 Inspection methods are given in ISO 10110-7 and ISO 9211-4. Coating imperfections are illustrated in annex A.

5.3.1 stain: Patchy, localized discoloration of the surface, caused by changes produced by chemical action.

5.3.2 abrasion: Surface damage from contact with a harder surface.

5.3.3 lint mark: Remains of fabric or paper fibres on an optical surface.

5.3.4 coating void: Local surface area inside the coated region which is uncoated when the remaining surface has the specified coating.

5.4 Volume imperfections

5.4.1 peeling: Partial separation of thin film(s) from the substrate surface at one end.

5.4.2 flaking: Partial separation of thin film portions from the substrate surface.

5.4.3 large spatter: Larger material particle than that defined in 5.1.2, i.e. having volume or depth to them.

5.4.4 large particle: Larger matter than that defined in 5.1.3, having volume or depth to it.

5.4.5 blister; bubble: Inclusion under or within the coating, attempting to lift up the film.

6 Other definitions

6.1 cone angle of aperture: Maximum range of angles of incidence.

6.2 useful area; clear aperture: Minimum surface area coated to specified tolerances.

6.3 rim: Uncoated surface area usually caused by tooling used to hold the component during treatment. In general, any area outside of the clear aperture.

6.4 witness sample: Samples which represent the actual coated component used for spectral and environmental testing. The details of witness samples and sampling procedures (e.g., material, surface texture, dimensions, number per batch, position in the coating chamber, etc.) shall be subject to agreement between supplier and user.

Annex A
(informative)

Illustrations of common types of coating imperfections

This annex gives illustrations of common types of coating imperfections in figures A.1 to A.4.

1 Pinhole (5.1.1)
2 Spatter (5.1.2)
3 Particle (5.1.3)
4 Fine dust (5.1.4)
5 Nodule (5.1.5)

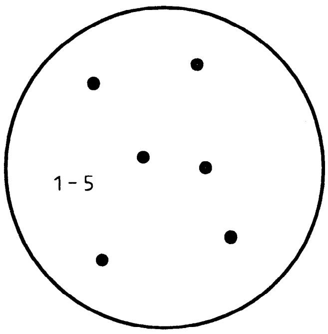

Figure A.1 — Point-like imperfections (5.1)

6 Scratch (5.2.1)
7 Hair line (5.2.2)
8 Crack (5.2.3)
9 Crazing (5.2.4)
10 Sleek (5.2.5)

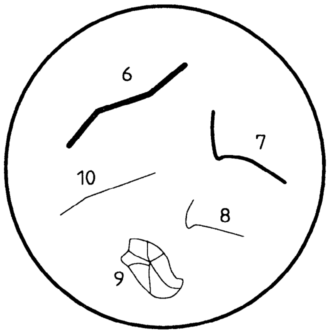

Figure A.2 — Line-like imperfections (5.2)

11 Stains (5.3.1)
12 Abrasions (5.3.2)
13 Lint marks (5.3.3)
14 Coating voids (5.3.4)

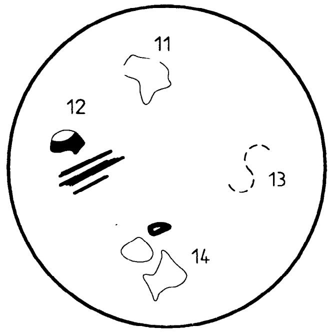

Figure A.3 — Area imperfections (5.3)

15 Peeling (5.4.1)
16 Flaking (5.4.2)
17 Large spatter (5.4.3)
18 Large particle (5.4.4)
19 Blister; bubble (5.4.5)

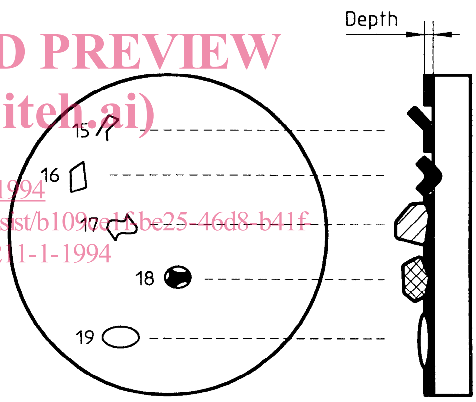

Figure A.4 — Volume imperfections (5.4)