INTERNATIONAL STANDARD

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Optics and photonics — Optical coatings —

Part 1:
Definitions

Optique et photonique — Traitements optiques —

Partie 1: Définitions

Reference number
ISO 9211-1:2010(E)

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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.

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 9211-1 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 9211-1:1994), 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 1: **Definitions**

IMPORTANT — The electronic file of this document contains colours which are considered to be useful for the correct understanding of the document. Users should therefore consider printing this document using a colour printer.

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 Basic definitions

2.1 Surface treatment

2.1.1
surface treatment of components and substrates
application of a coating of material(s) intended to modify the optical, physical or chemical characteristics originally possessed by the surface of a component

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

2.1.2
incident medium
medium from which the electromagnetic radiation enters the coating

2.1.3
emergent medium
medium into which the electromagnetic radiation exits the coating

NOTE Besides acting as mechanical support, the substrate carrying the coating physically can constitute the incident medium and/or the emergent medium.

2.2 Optical properties of a coated surface

2.2.1 General

The optical properties of a coated surface are characterized by spectrophotometric values. These values relate to the energy transported by electromagnetic waves (radiant or luminous) and they vary as a function of the wavelength, the angle of incidence, and the state of polarization. Additional influences may be caused by scattering.

NOTE 1 The functional spectral dependency is generally indicated by writing the wavelength, λ, in parentheses as part of the symbol.

NOTE 2 The wavelength (λ) can be replaced by the wavenumber (σ) or the photon energy ($h\nu$). h = Planck constant; ν = frequency. The units recommended are the nanometre (nm) or the micrometre (µm) for the wavelength, the reciprocal centimetre (cm^{-1}) for the wavenumber and the electron volt (eV) for the photon energy.

2.2.2
spectral transmittance
$\tau(\lambda)$
ratio of the spectral concentration of radiant or luminous flux transmitted to that of the incident radiation

ISO 80000-7:2008, definition 7-22.3.

NOTE Spectral transmittance is related to spectral optical density $D(\lambda)$ by the formula: $\tau(\lambda) = 10^{-D(\lambda)}$.

2.2.3
spectral reflectance
$\rho(\lambda)$
ratio of the spectral concentration of radiant or luminous flux reflected, to that of the incident radiation

ISO 80000-7:2008, definition 7-22.2.

2.2.4
spectral absorptance
$\alpha(\lambda)$
ratio of the spectral concentration of radiant or luminous flux absorbed, to that of the incident radiation

ISO 80000-7:2008, definition 7-22.1.

2.2.5
spectral scattering
change of the spatial distribution of a beam of radiation spread in many directions by a surface or a medium without any change of frequency of the monochromatic components of which the radiation is composed

NOTE 1 The quantities defined in 2.2.1.1 to 2.2.1.4 are interrelated as follows:

$$1 = \tau(\lambda) + \rho(\lambda) + \alpha(\lambda)$$

with $\tau(\lambda) = \tau_r(\lambda) + \tau_d(\lambda)$

$$\rho(\lambda) = \rho_r(\lambda) + \rho_d(\lambda)$$

where

$\tau_r(\lambda)$ is the regular spectral transmittance (specular);

$\rho_r(\lambda)$ is the regular spectral reflectance (specular);

$\tau_d(\lambda)$ is the diffuse spectral transmittance (scattered);

$\rho_d(\lambda)$ is the diffuse spectral reflectance (scattered).

NOTE 2 If necessary, these values can be represented as an average over a wavelength range from λ_1 to λ_2 as follows:

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

where $\Delta\lambda = (\lambda_2 - \lambda_1)/m$.

2.2.6
refractive index
$n(\lambda)$
ratio of the velocity of propagation of electromagnetic radiation in a vacuum to the velocity of propagation of electromagnetic radiation in a medium

2.2.7
angle of incidence
angle between the normal to the surface and the incident ray

2.2.8
plane of incidence
plane incorporating the normal to the surface and the incident ray

2.3 Colorimetric parameters

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

2.4 Polarization

2.4.1 General

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.

2.4.2
linearly polarized radiation
polarization where the orientation of the electric field vector remains constant

NOTE 1 s-polarization refers to linear polarization where the electric field vector is perpendicular to the plane of incidence.

NOTE 2 p-polarization refers to linear polarization where the electric field vector is parallel to the plane of incidence.

2.4.3
elliptically polarized radiation
polarization where the projection of the electric field vector on to a plane normal to the direction of propagation describes an ellipse

2.4.4
circularly polarized radiation
polarization where the projection of the electric field vector on to a plane normal to the direction of propagation describes a circle

2.4.5
randomly polarized radiation
polarization where the orientation of the electric field vector of linearly polarized radiation varies randomly with time

2.4.6
unpolarized radiation
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 change is completely random

2.5 Phase relations

2.5.1
phase change
$\mathrm{d}\Phi$
angle difference, $\Phi - \Phi_0$, represents the phase change between an electromagnetic wave and a reference wave with its electric field vector given by

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

where

E is the electric field vector;

A is the amplitude vector;

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

$$E_0 = A\cos\left(\frac{2\pi vt}{\lambda} - \Phi_0\right)$$

2.5.2
phase retardation
$\Delta\Phi$
difference of phase change between the s- and p-components of the electric field vector, $\Delta\Phi = \mathrm{d}\Phi_\mathrm{p} - \mathrm{d}\Phi_\mathrm{s}$.

3 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.

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 shall be indicated.

Table 1 — Definitions of coatings by function

Principal function	Code designation	Definition	Example of application
Reflecting	RE	Coating increasing the reflectance of an optical surface over a specified wavelength range.	Laser mirror
Antireflecting	AR	Coating reducing the reflectance of an optical surface over a specified wavelength range and usually increasing the transmittance.	AR coated lens
Beam splitting	BS	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 beamsplitter Partial reflector
Attenuating	AT	Coating reducing the transmittance in essentially a non-selective manner over a specified wavelength range.	Neutral density filter
Filtering a) Bandpass b) Band rejection	FI FI-BP FI-BR	Coating modifying the transmittance in a selective manner over a specified wavelength range.	Laser line selection filter Raman notch filter
Selecting or combining a) Long pass b) Short pass	SC SC-LP SC-SP	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 mirror Beam combiner Cold light mirror NIR cut filter
Polarizing	PO	Coating controlling the state of polarization of the emergent electromagnetic radiation, over a specified wavelength range.	Polarizer Non-polarizing beamsplitter
Phase changing	PC	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 retarder
Absorbing	AB	Coating absorbing a specified value of the incident flux over a specified wavelength range.	Light trap UV absorber
Supplementary	SU	Coating providing a non-optical property; this function is often combined with an optical function.	Electrical conductivity Chemical or mechanical protection

4 Definitions of common coating imperfections

NOTE The inspection methods are described in ISO 9211-4 and ISO 14997[2]. Examples of coating imperfections are given in Annex A.

4.1 Point-like imperfections

4.1.1
pinhole
very small hole in the thin film

4.1.2
spatter
imperfections that result when small chunks of coating material fly on to the substrate surface and adhere there in the coating process

4.1.3
particle
small piece of matter on/in the film

4.1.4
fine dust
number (often numerous) of small pieces of matter on/in the film

4.1.5
nodule
small lump (usually of coating material) in the film

4.2 Line-like imperfections

4.2.1
scratches
marking or tearing of a surface which looks as though it has been done by either a sharp or rough instrument

NOTE Scratches occur on optical surfaces in all degrees from various accidental causes.

4.2.2
hairline scratch
very fine, smooth scratch, usually straight

NOTE The hairline scratch is characterized by its uniqueness and its straightness. Other scratches can be curved, or appear straight or curved, multiple, adjacent or without contact.

4.2.3
crack
fracture in the film

4.2.4
crazing
pattern of fractures in the film (usually due to differential thermal stress)

4.3 Area-like imperfections

4.3.1
stain
patchy, localized discoloration of the surface, e.g. caused by chemical reactions

4.3.2
abrasion
surface damage caused by rubbing against another surface

4.3.3
lint mark
remains of fabric or paper fibres on an optical surface

4.3.4
void
small uncoated area inside the region which is coated

4.4 Volume-like imperfections

4.4.1
peeling
partial separation of thin film(s) originating from the peripheral zone of the coated area

4.4.2
flaking
partial separation of thin film(s) originating from the inner region of the coated area

4.4.3
blister
bubble
inclusion under or within the coating, which lifts the film

5 Other terms and definitions

5.1
clear aperture
surface area to meet specifications

5.2
rim
any area outside of the clear aperture

5.3
witness sample
samples that represent the actual coated component used for spectral and environmental testing

NOTE The details of witness samples and sampling procedures (e.g., material, surface texture, dimensions, number per batch, position in the coating chamber, etc.) is subject to agreement between supplier and user.

Annex A
(informative)

Micrographs of common types of coating imperfection

This annex gives micrographs of common types of coating imperfections in Figures A.1 to A.16.

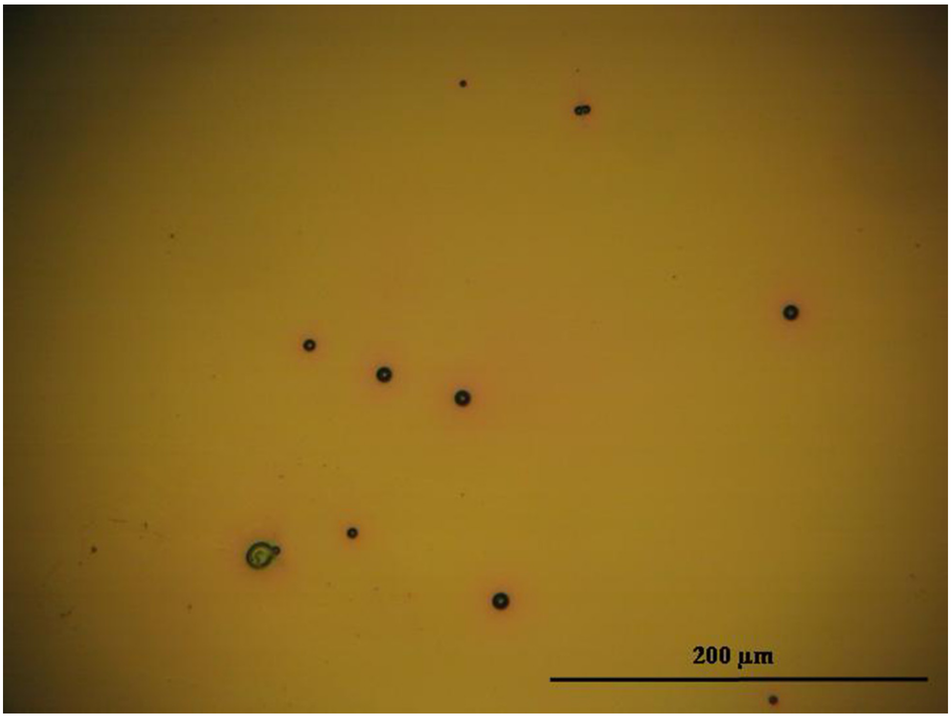

Figure A.1 — Pinhole

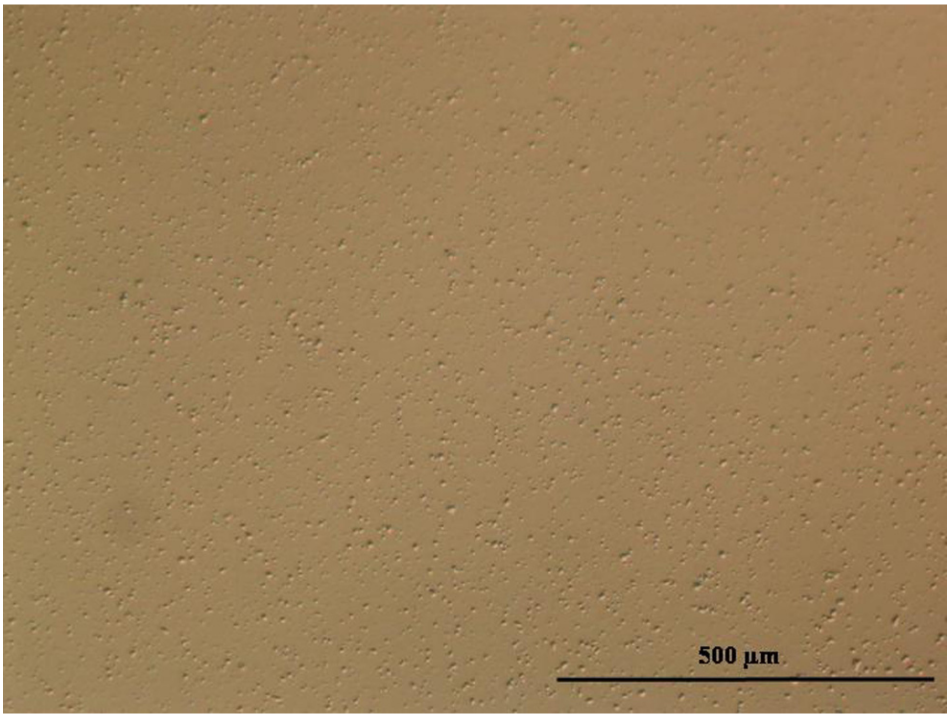

Figure A.2 — Spatter

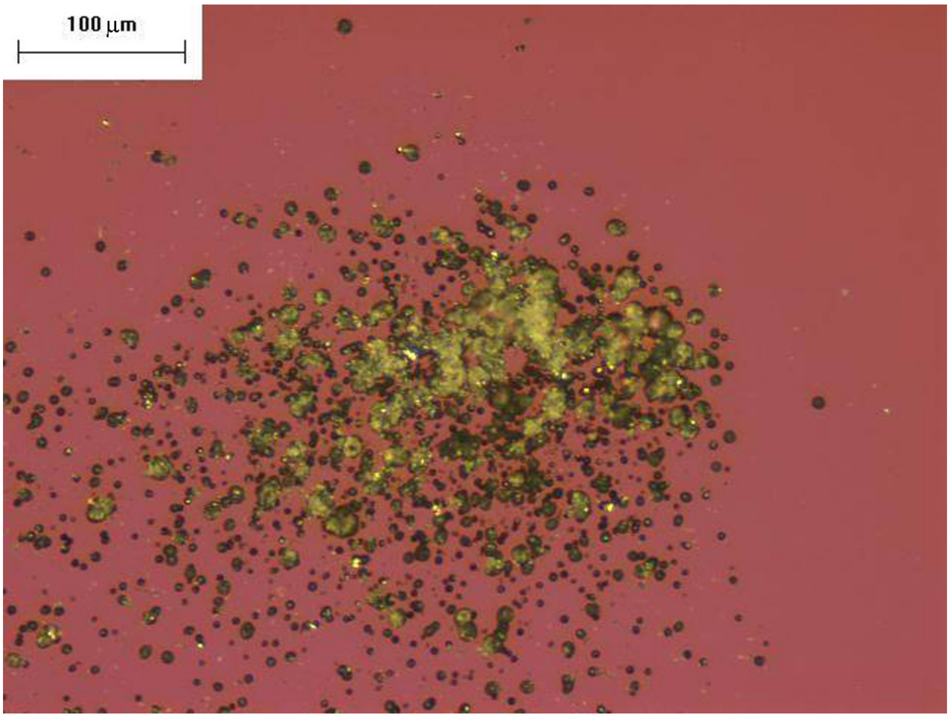

Figure A.3 — Particle

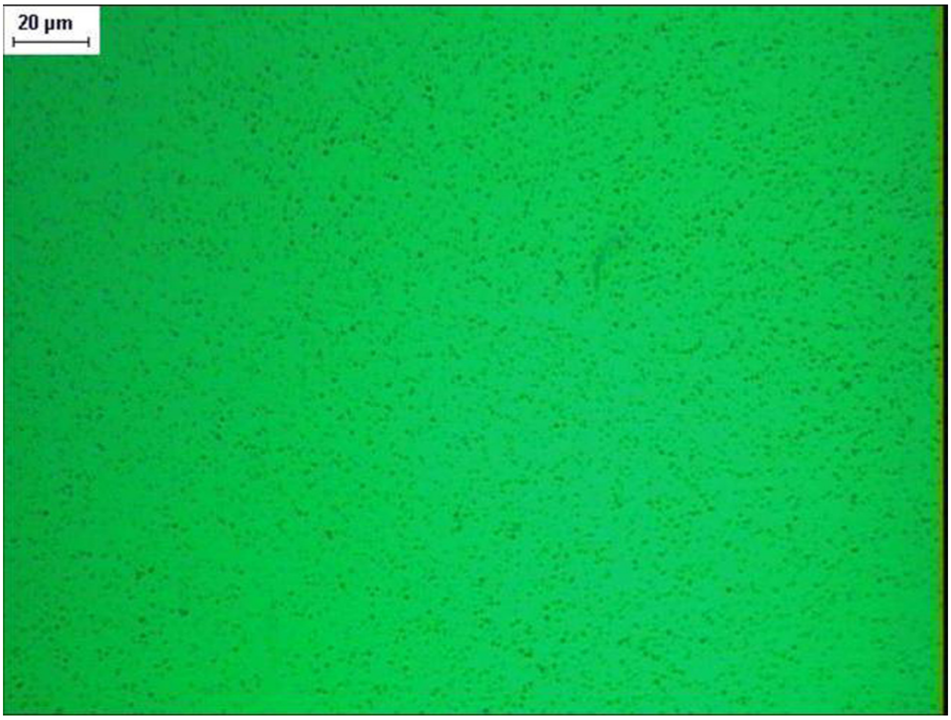

Figure A.4 — Fine dust

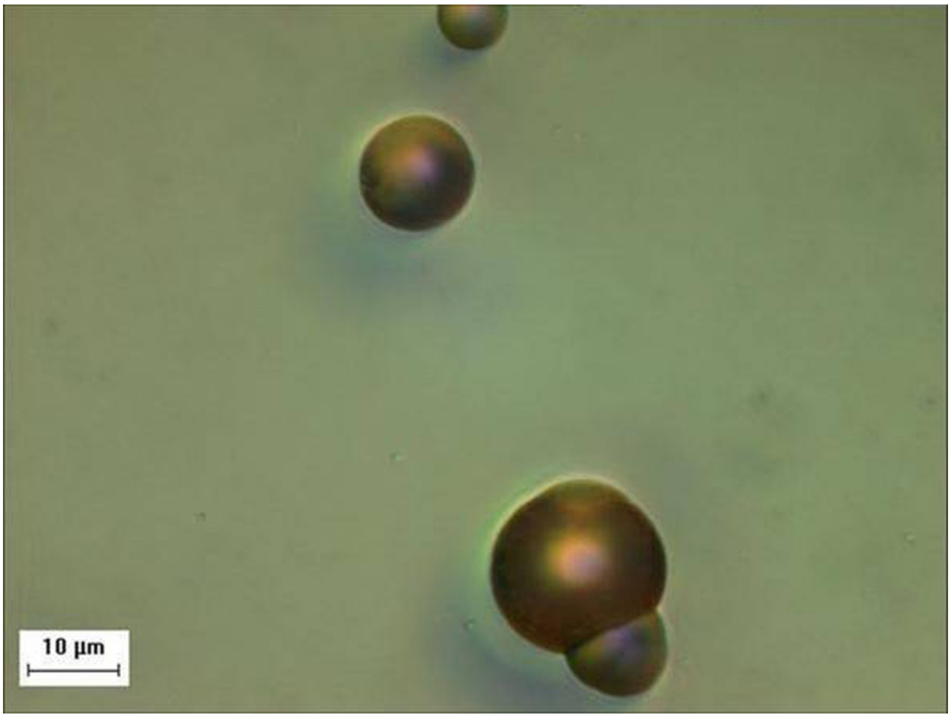

Figure A.5 — Nodule

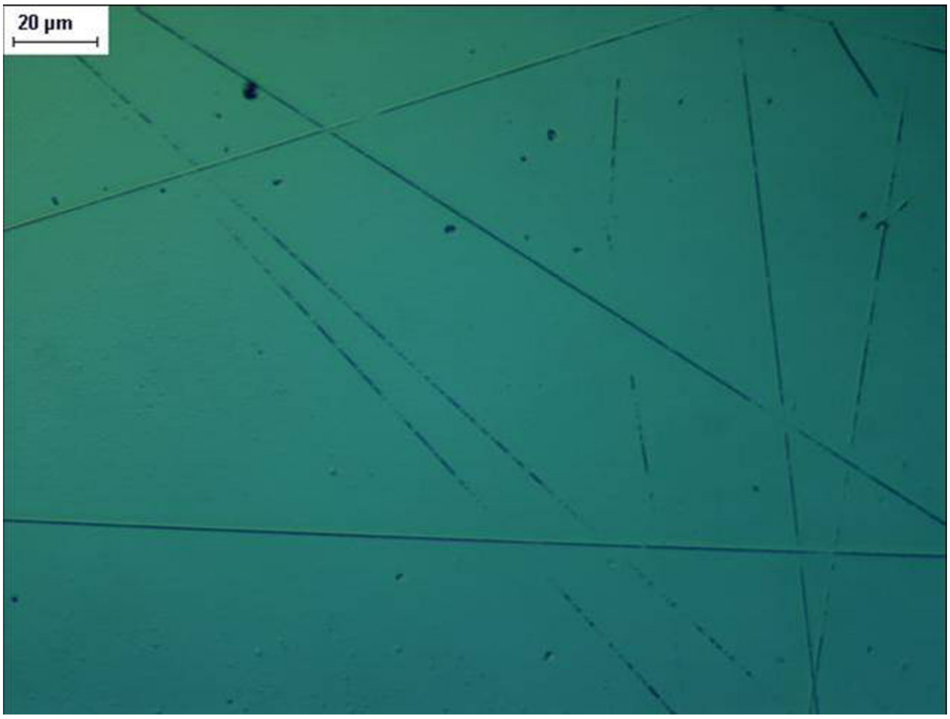

Figure A.6 — Scratches

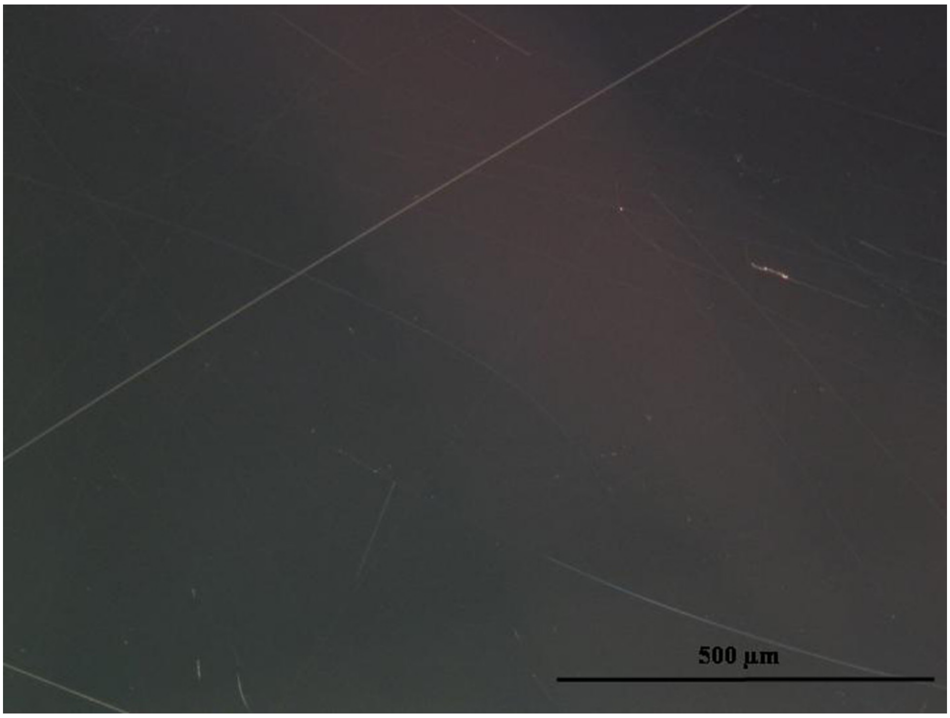

Figure A.7 — Hairline scratch

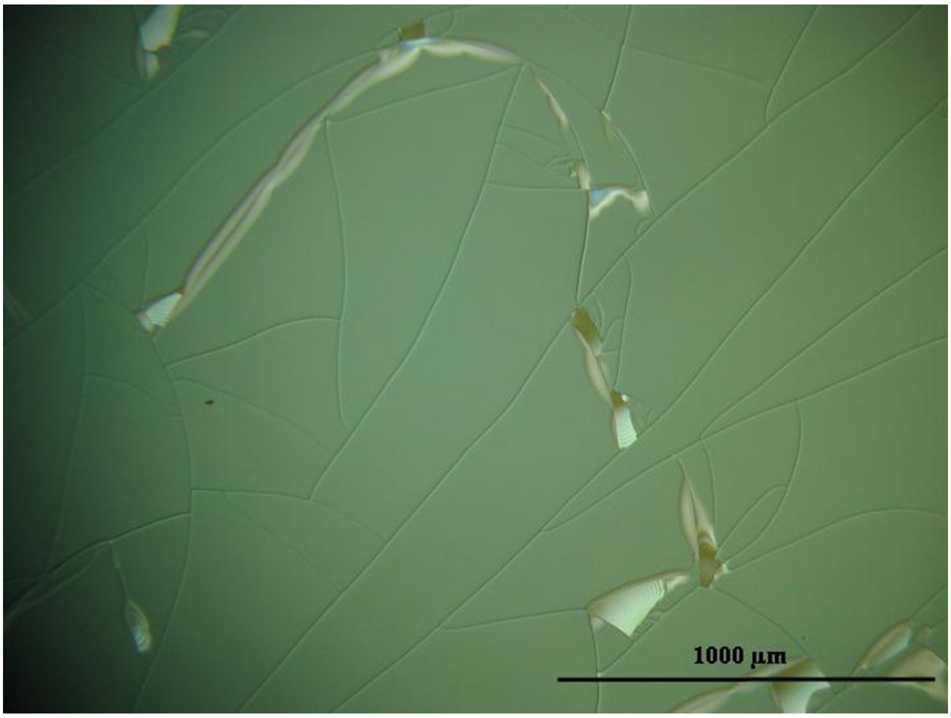

Figure A.8 — Crack

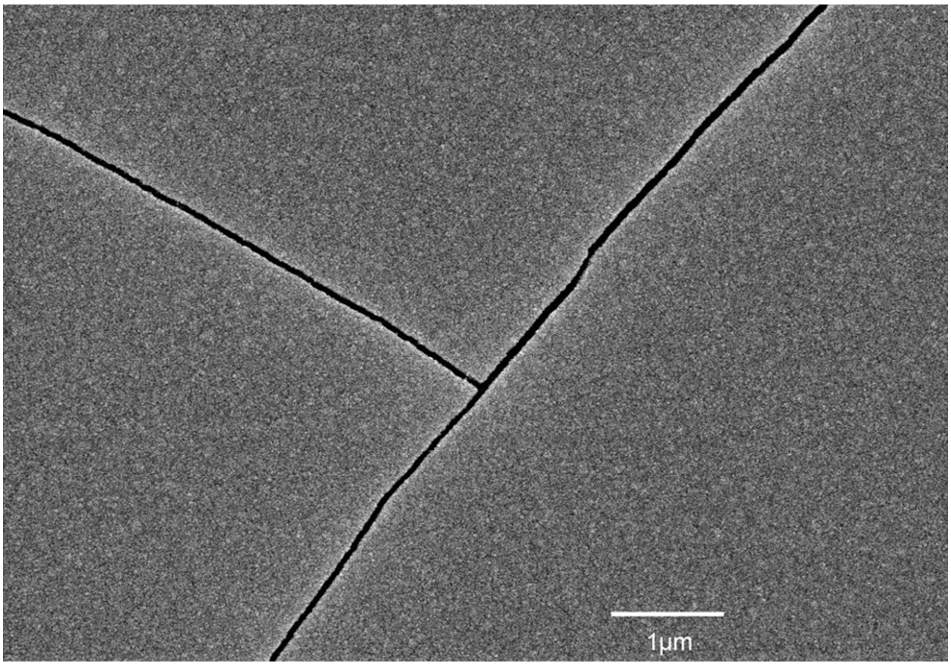

Figure A.9 — Crazing

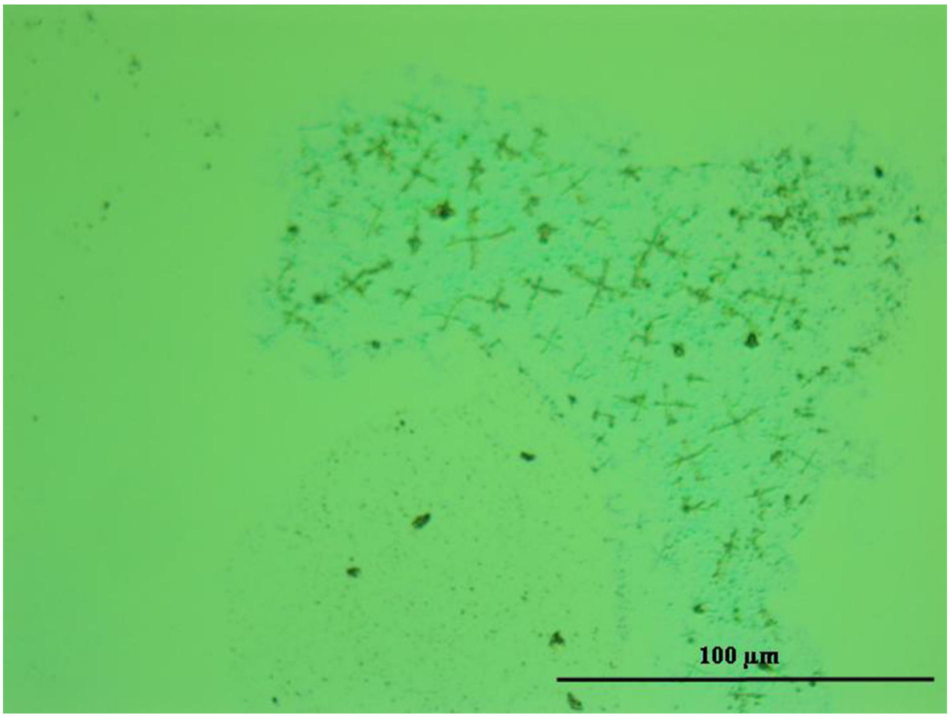

Figure A.10 — Stain

Figure A.11 — Abrasion

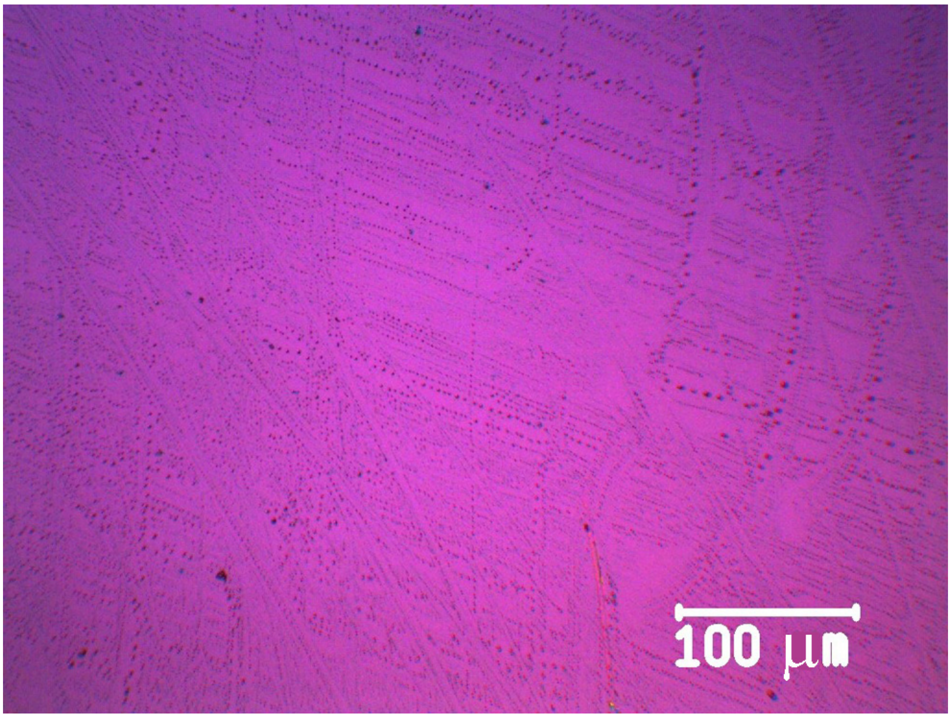

Figure A.12 — Lint mark

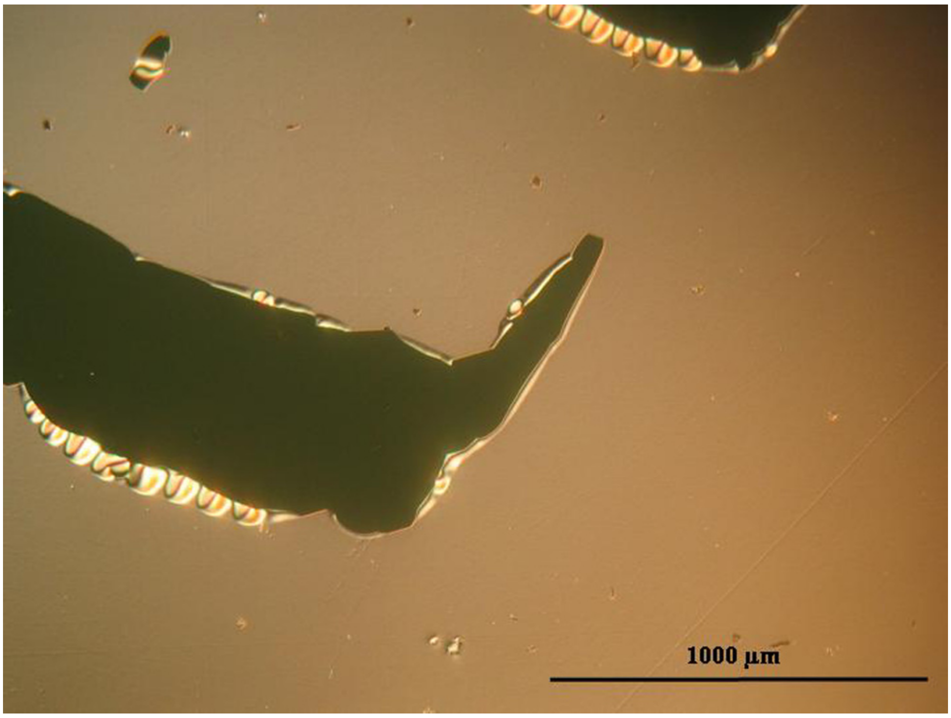

Figure A.13 — Void

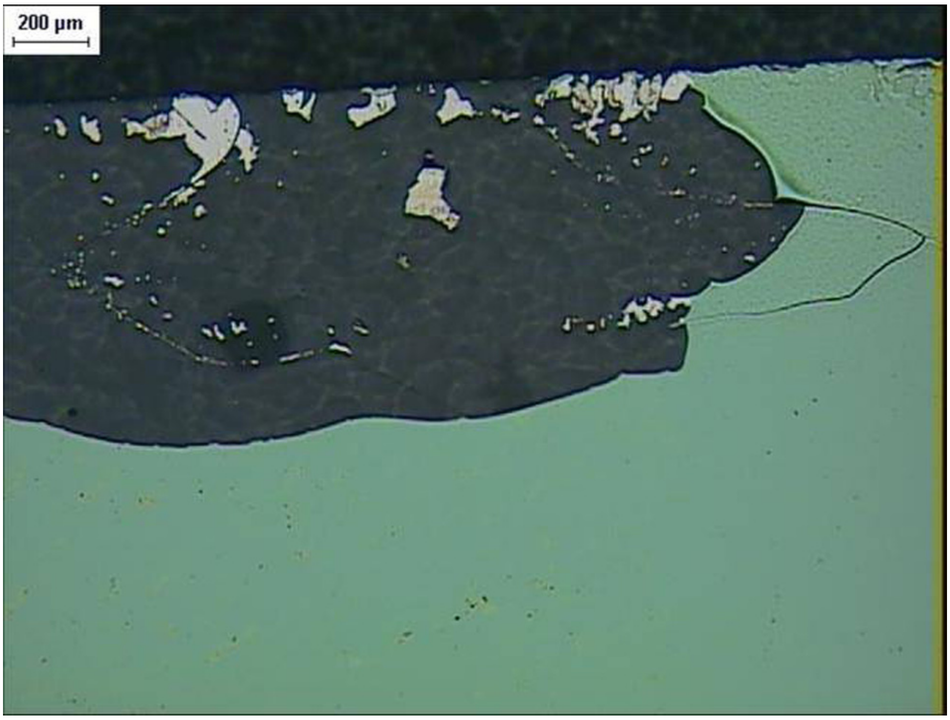

Figure A.14 — Peeling

Figure A.15 — Flaking

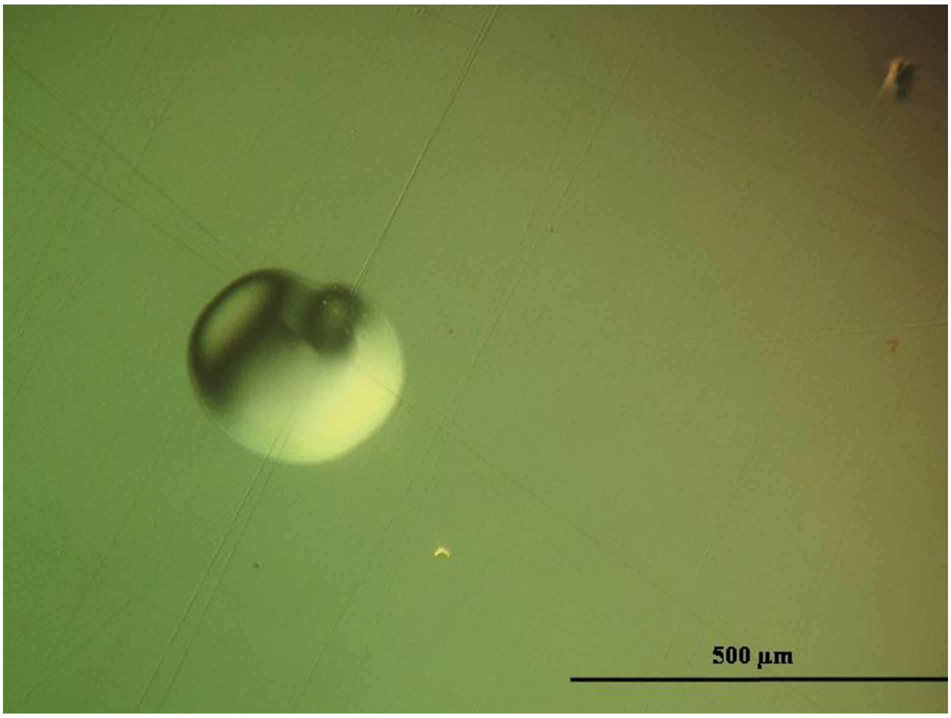

Figure A.16 — Blister

Bibliography

[1] ISO 6286, *Molecular absorption spectrometry —Vocabulary — General — Apparatus*

[2] ISO 14997, *Optics and optical instruments — Test methods for surface imperfections of optical elements*

[3] ISO 80000-7:2008, *Quantities and units — Part 7: Light*

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