



International Standard

ISO 9211-1

Optics and photonics — Optical coatings —

Part 1: Vocabulary

Optique et photonique — Traitements optiques —

Partie 1: Vocabulaire

**Fourth edition
2024-02**

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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 document 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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This document was prepared by Technical Committee ISO/TC 172, *Optics and photonic*, Subcommittee SC 3, *Optical materials and components*.

This fourth edition cancels and replaces the third edition (ISO 9211-1:2018), which has been technically revised.

The main changes are as follows:

- addition of the definition of spectral optical density;
- explanations of subscript for spectral average;
- explanations of average transmittance, reflectance, absorptance and optical density over wavelength or wave number.

A list of all parts in the ISO 9211 series can be found on the ISO website.

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

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 can be caused by scattering.

NOTE 1 The functional spectral dependency is generally indicated by including 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.

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 can influence the polarization state of the emergent radiation. It might then be necessary to indicate the orientation of the electric field vector in relation to the plane of incidence.

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 may be indicated.

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. Colorimetric parameters are not part of this standard.

Examples of coating imperfections are given in [Annex A](#). Test methods for the surface imperfections are described in ISO 14997.

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Optics and photonics — Optical coatings —

Part 1: Vocabulary

WARNING — 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

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

This document 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.

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 11145, *Optics and photonics — Lasers and laser-related equipment — Vocabulary and symbols*

ISO 80000-7, *Quantities and units — Part 7: Light and radiation*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 11145 and ISO 80000-7 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 <https://www.electropedia.org/>

3.1 Basic terms and definitions

3.1.1 General terms

3.1.1.1

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 1 to entry: 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.

3.1.1.2

incident medium

medium from which the electromagnetic radiation enters a coating

3.1.1.3

emergent medium

medium into which the electromagnetic radiation exits a coating

Note 1 to entry: Besides acting as mechanical support, the substrate carrying the coating physically can constitute the incident medium and/or the emergent medium.

3.1.1.4

clear aperture

effective aperture

surface area to meet specifications

3.1.1.5

rim

surface area outside of the clear aperture

3.1.1.6

witness sample

sample that represents the actual coated component used for spectral and environmental testing

Note 1 to entry: The details of witness samples and measurements (e.g. material, surface texture, dimensions, number per batch, position in the coating chamber, etc.) is subject to agreement between manufacturer and customer.

3.1.2 Terms for optical properties of a coated surface

3.1.2.1

spectral transmittance

$\tau(\lambda)$

ratio of the spectral radiant or luminous flux transmitted to that of the incident radiant or luminous flux

Note 1 to entry: Spectral transmittance is related to spectral optical density $D(\lambda)$ by the formula: $\tau(\lambda) = 10^{-D(\lambda)}$.

Note 2 to entry: Wherever the Greek letter τ is mistakable $T(\lambda)$ may be used.

3.1.2.2

average spectral transmittance over wavelength

$\tau_{\text{ave}}(\lambda_1 \text{ to } \lambda_2)$

average of the spectral transmittance over a specified wavelength range

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

where

$$\Delta\lambda = \frac{\lambda_2 - \lambda_1}{m}$$

Note 1 to entry: The average spectral transmittance over wavelength has a different value than the average transmittance over wavenumber even if the range of wavelength is equivalent to the range of wavenumber.

Note 2 to entry: The range of wavelength and units (λ_1 to λ_2) may be given.

Note 3 to entry: The index “avg” may be used instead of “ave”.

3.1.2.3

average spectral transmittance over wavenumber

$\tau_{\text{ave}}(\sigma_1 \text{ to } \sigma_2)$

average of the spectral transmittance over a specified wavenumber range

$$\tau_{\text{ave}}(\sigma_1 \text{ to } \sigma_2) = \frac{\int_{\sigma_1}^{\sigma_2} \tau(\sigma) d\sigma}{\sigma_2 - \sigma_1} \approx \frac{\sum_{i=1}^m \tau(\sigma_i) \Delta\sigma}{\sigma_2 - \sigma_1} = \frac{\sum_{i=1}^m \tau(\sigma_i)}{m}$$

where

$$\Delta\sigma = \frac{\sigma_2 - \sigma_1}{m}$$

Note 1 to entry: The average spectral transmittance over wavelength has a different value than the average transmittance over wavenumber even if the range of wavelength is equivalent to the range of wavenumber.

Note 2 to entry: The average spectral transmittance over wavenumber is used mainly for large ranges, i.e. broadband filters in the Infrared.

Note 3 to entry: The range of wavenumber and units (σ_1 to σ_2) may be given.

Note 4 to entry: The index “avg” may be used instead of “ave”.

3.1.2.4

spectral reflectance

$\rho(\lambda)$

ratio of the spectral radiant or luminous flux reflected to that of the incident radiant or luminous flux

Note 1 to entry: Wherever the Greek letter ρ is mistakable $R(\lambda)$ may be used.

Note 2 to entry: Average spectral reflectance over wavenumber or over wavelength can be calculated in the same manner as that shown for spectral transmittance.

3.1.2.5

spectral absorptance

$\alpha(\lambda)$

ratio of the spectral radiant or luminous flux absorbed to that of the incident radiant or luminous flux

Note 1 to entry: Wherever the Greek letter α is mistakable $A(\lambda)$ may be used.

Note 2 to entry: The quantities defined in [3.1.2.1](#), [3.1.2.4](#) and [3.1.2.5](#) 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 specular spectral transmittance (regular);

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

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

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

Note 3 to entry: Specular transmittance and specular reflectance are sometimes referred to as regular transmittance and regular reflectance, respectively.

Note 4 to entry: Average spectral absorptance and optical density over wavenumber or over wavelength can be calculated in the same manner as that shown for spectral transmittance.

3.1.2.6

spectral optical density

$D(\lambda)$

logarithm to the base 10 of the reciprocal of the *spectral transmittance* ([3.1.2.1](#))

$$D(\lambda) = \lg \frac{1}{\tau(\lambda)}$$

[SOURCE: ISO 23364:2021, 3.3.1]

Note 1 to entry: Average spectral optical density over wavenumber or over wavelength can be calculated in the same manner as that shown for spectral transmittance.

3.1.2.7

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

3.1.2.8

refractive index

$n(\lambda)$

ratio of the velocity of propagation of electromagnetic radiation in vacuum to the velocity of propagation of electromagnetic radiation in a medium

Note 1 to entry: The wavelength is defined in vacuum.

3.1.2.9

angle of incidence

θ

angle between the normal to the optical surface and the incident ray

Note 1 to entry: Unless otherwise specified, the angle of incidence is equal to 0°; this means the incident rays are normal to the optical surface.

3.1.2.10

plane of incidence

plane incorporating the normal to the surface and the incident ray

3.1.3 Terms for polarization

3.1.3.1

linear polarization

property of electromagnetic radiation in which the electric field vector oscillates along a fixed direction

Note 1 to entry: The oscillation is confined to a plane containing the direction of propagation of the radiation, in a homogeneous optical medium.

Note 2 to entry: A source is called “linearly polarized” if the degree of linear polarization is greater than 0,9 and the polarization direction is constant over time.

Note 3 to entry: S-polarization refers to linear polarization where the electric field vector is perpendicular to the plane of incidence.

Note 4 to entry: P-polarization refers to linear polarization where the electric field vector is parallel to the plane of incidence.

[SOURCE: ISO 11145:2018, 3.12.4, modified — In Note 2 the term “laser beam” has been replaced with “source”, and Notes 3 and 4 have been added.]

3.1.3.2

elliptical polarization

property of electromagnetic radiation in which the electric field vector rotates about the direction of propagation at the radiation frequency and periodically oscillates in amplitude in a homogeneous optical medium

Note 1 to entry: The terminal point of the electric field vector describes an ellipse.

[SOURCE: ISO 11145:2018, 3.12.3]

3.1.3.3

circular polarization

property of electromagnetic radiation in which the electric field vector is of constant amplitude and rotates about the direction of propagation at a frequency equal to the radiation frequency in a homogeneous optical medium

[SOURCE: ISO 11145:2018, 3.12.2]

3.1.3.4

random polarization

state in which a beam of electromagnetic radiation is composed of two linearly polarized beams of electromagnetic radiation having orthogonal fixed polarization directions and having amplitudes that vary randomly over time with respect to each other

[SOURCE: ISO 11145:2018, 3.12.7]

3.1.3.5

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

3.1.4 Phase related terms

3.1.4.1

phase change

$d\Phi$

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

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

3.1.4.2

phase retardation

$\Delta\Phi$
difference of phase change between the P- and S-polarization components of the electric field vector given by

$$\Delta\Phi = d\Phi_P - d\Phi_S = (\Phi_P - \Phi_{P0}) - (\Phi_S - \Phi_{S0})$$

where

$d\Phi_P$ is the phase change for the P-polarization component

$d\Phi_S$ is the phase change for the S-polarization component

Φ_{P0} is the phase of the P-polarization component of the reference wave

Φ_{S0} is the phase of the S-polarization component of the reference wave

3.2 Designations of coatings by principal function

3.2.1 Reflecting function

3.2.1.1

RE

coating which increases the reflectance of an optical surface over a specified wavelength range

3.2.1.2

HR

coating which creates a high reflectance of an optical surface over a specified wavelength range without defined transmittance

3.2.1.3

PR

coating which creates a defined (partial) reflectance and a defined transmittance of an optical surface over a specified wavelength range

3.2.2 Antireflecting function

3.2.2.1

AR

coating which reduces the reflectance of an optical surface over a specified wavelength range and usually increasing the transmittance

3.2.3 Beam splitting function

3.2.3.1

BS

coating which separates 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

3.2.4 Attenuating function

3.2.4.1

AT

coating which reduces the transmittance in essentially a non-selective manner over a specified wavelength range

3.2.5 Bandpass or band rejection filtering function

3.2.5.1

FI

which modifies the transmittance in a selective manner over a specified wavelength range

3.2.5.2

FI-BP

coating which modifies the transmittance by passing a specified wavelength range

Note 1 to entry: If there is no ambiguity the code designation "BP" may be used.

3.2.5.3

FI-BR

coating which modifies the transmittance by rejecting a specified wavelength range

Note 1 to entry: If there is no ambiguity the code designation "BR" may be used.

3.2.6 Selecting or combining function

3.2.6.1

SC

coating which divides the incident flux into two or more beams each one covering a limited spectral region and being propagated either by reflection or by transmission

Note 1 to entry: The reverse path combines beams of different spectral regions

3.2.6.2

SC-LP (Long pass)

coating of type SC where the spectral region of longer wavelength is transmitted

Note 1 to entry: If there is no ambiguity the code designation "LP" may be used.

3.2.6.3

SC-SP (Short pass)

coating of type SC where the spectral region of shorter wavelength is transmitted

Note 1 to entry: If there is no ambiguity the code designation "SP" may be used.

3.2.7 Polarizing function

3.2.7.1

PO

coating which determines the state of polarization of the emergent electromagnetic radiation over a specified wavelength range

3.2.8 Phase changing function

3.2.8.1

PC

coating which determines 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

3.2.9 Absorbing function

3.2.9.1

AB

coating which absorbs a specified value of the incident flux over a specified wavelength range

3.2.10 Supplementary function

3.2.10.1

SU

coating which provides a non-optical property

Note 1 to entry: This function is often combined with an optical function.

Table 1 — Definitions of coatings by function

Principal function	Code designation	Definition	Example of application
Reflecting	RE	Coating which increases the reflectance of an optical surface over a specified wavelength range.	Metal mirror
	HR	Coating which creates a high reflectance of an optical surface over a specified wavelength range without defined transmittance.	Laser mirror
	PR	Coating which creates a defined (partial) reflectance and a defined transmittance of an optical surface over a specified wavelength range.	Outcoupler, cavity ring-down mirror
Antireflecting	AR	Coating which reduces the reflectance of an optical surface over a specified wavelength range and usually increasing the transmittance.	AR coated lens
Beam splitting	BS	Coating which separates 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 beam-splitter
Attenuating	AT	Coating which reduces 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 ^a	Coating which modifies the transmittance in a selective manner over a specified wavelength range.	Laser line selection filter Raman notch filter
Selecting or combining a) Longpass b) Shortpass	SC SC-LP SC-SP ^b	Coating which divides the incident 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 which determines the state of polarization of the emergent electromagnetic radiation, over a specified wavelength range.	Polarizer Non-polarizing beamsplitter
^a If there is no ambiguity the code designation "BP" or "BR" may be used.			
^b If there is no ambiguity the code designation "LP" or "SP" may be used.			

Table 1 (continued)

Principal function	Code designation	Definition	Example of application
Phase changing	PC	Coating which determines 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 which absorbs a specified value of the incident flux over a specified wavelength range.	Light trap UV absorber
Supplementary	SU	Coating which provides a non-optical property; this function is often combined with an optical function.	Electrical conductivity Chemical or mechanical protection
^a If there is no ambiguity the code designation "BP" or "BR" may be used. ^b If there is no ambiguity the code designation "LP" or "SP" may be used.			

3.3 Terms related to common coating imperfections

3.3.1 Point-like imperfections

3.3.1.1 pinhole

very small hole in the coating

3.3.1.2 spatter

imperfection that results when small chunks of coating material fly on to the substrate surface and adhere there in the coating process

3.3.1.3 particle

small piece of matter on/in/under the coating

3.3.1.4 fine dust

number (often numerous) of small pieces of matter on/in/under the coating

3.3.1.5 nodule

small lump (usually of coating material) in the coating

3.3.2 Line-like imperfections

3.3.2.1 scratch

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

Note 1 to entry: Scratches occur on optical surfaces in all degrees from various accidental causes.

3.3.2.2 hairline scratch

very fine, smooth scratch without visible conchoidal fracturing at the edges, usually straight

Note 1 to entry: 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.

3.3.2.3

sleek

a **hairline scratch** which is only visible over a narrow range of angles

Note 1 to entry: Sleeks are typically less than 0,003 millimetres wide.

3.3.2.4

crack

fracture in the coating

3.3.2.5

crazing

pattern of fractures in the coating (usually due to differential thermal stress)

3.3.3 Area-like imperfections

3.3.3.1

stain

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

3.3.3.2

abrasion

surface damage caused by rubbing against another surface

3.3.3.3

lint mark

remain of fabric or paper fibres on an optical surface

3.3.3.4

void

small uncoated portion inside the coated area

3.3.3.6

haze

an area imperfection that diffuses reflected or transmitted light and appears milky or cloudy

3.3.3.7

discoloration

an area imperfection of a coated surface that causes the coating to appear as a different colour over different parts of the aperture.

3.3.4 Volume-like imperfections

3.3.4.1

peeling

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

3.3.4.2

flaking

partial separation of thin film(s) originating from the inner zone of the coated area

3.3.4.3

blister

bubble

inclusion under or within the coating, which causes a partial separation of thin films(s)

Annex A (informative)

Micrographs of common types of coating imperfections

This annex gives micrographs of common types of coating imperfections. See [Figures A.1](#) to [A.16](#).

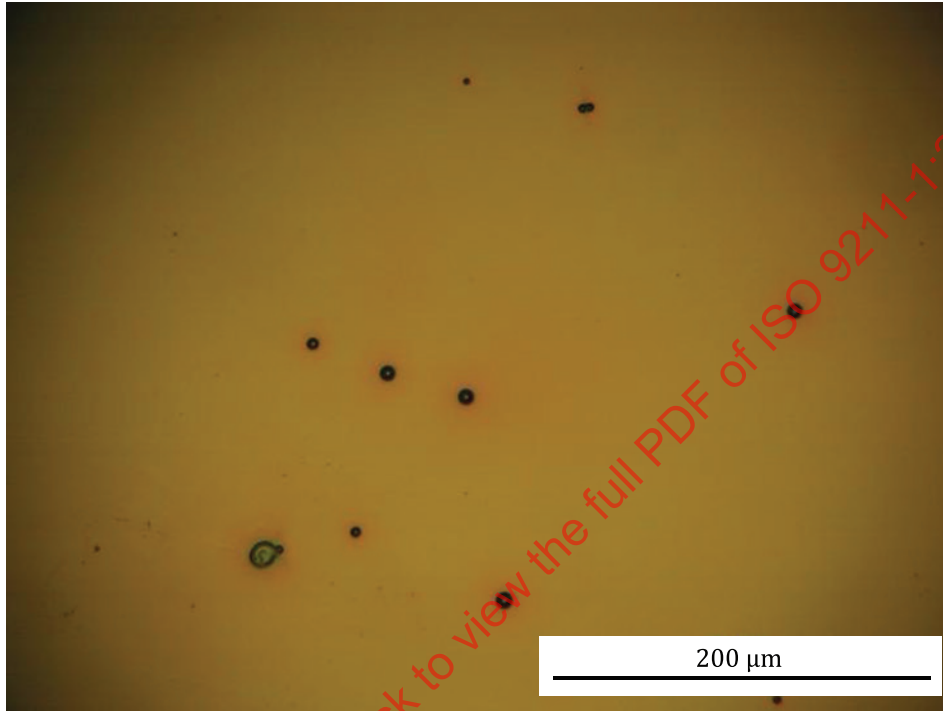


Figure A.1 — Pinhole

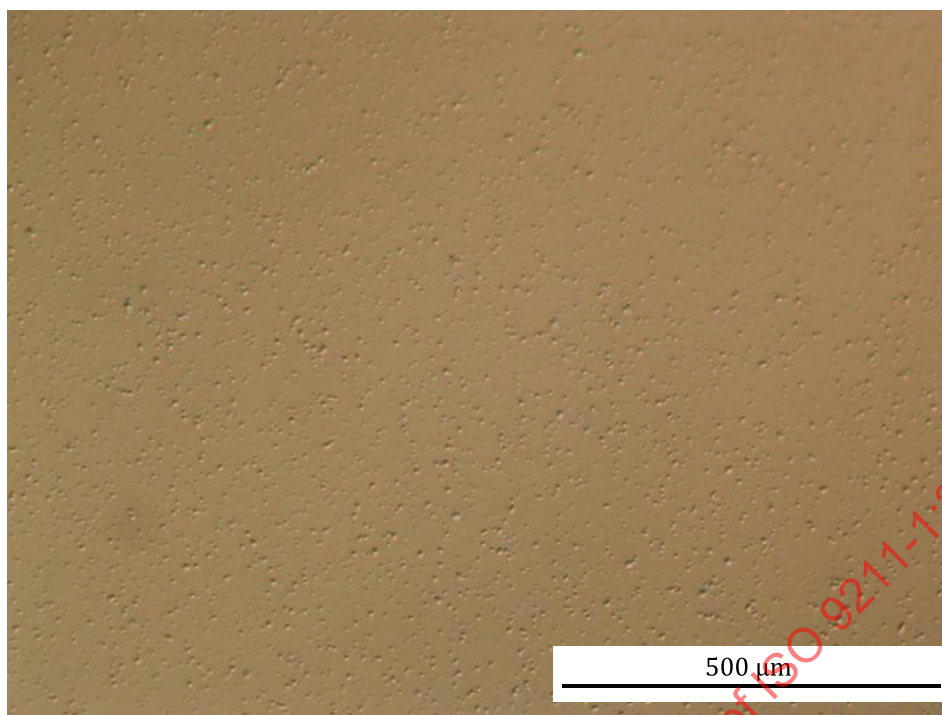


Figure A.2 — Spatter

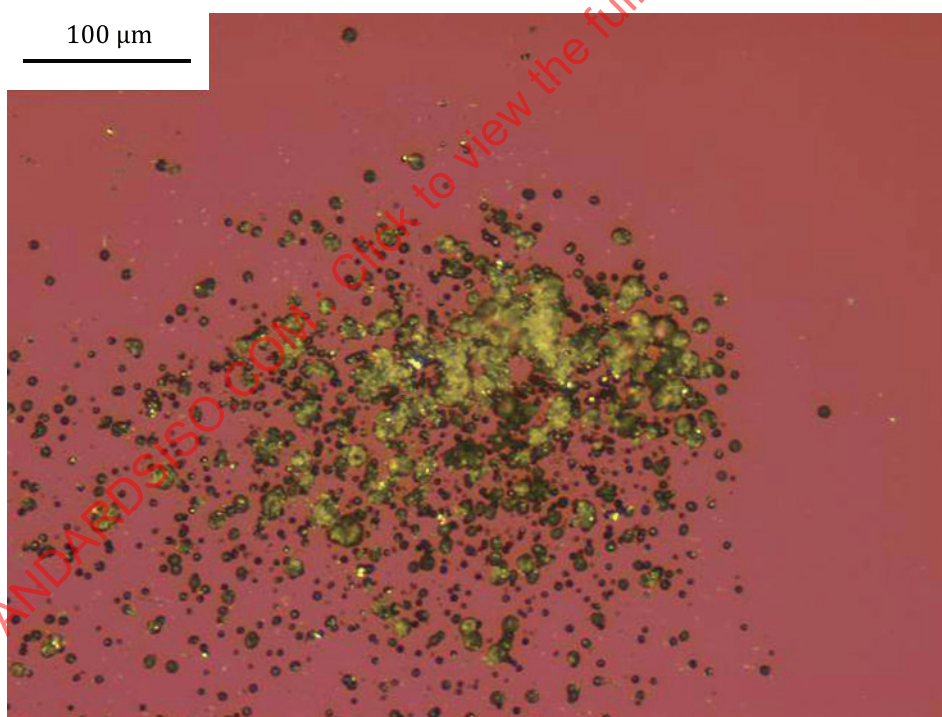


Figure A.3 — Particle



Figure A.4 — Fine dust

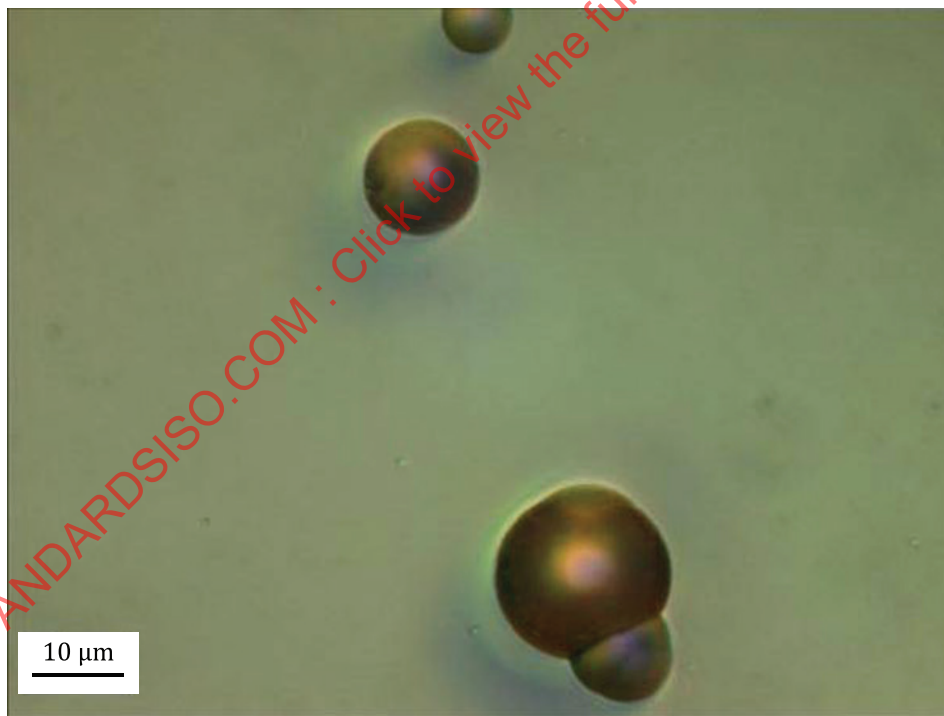


Figure A.5 — Nodule

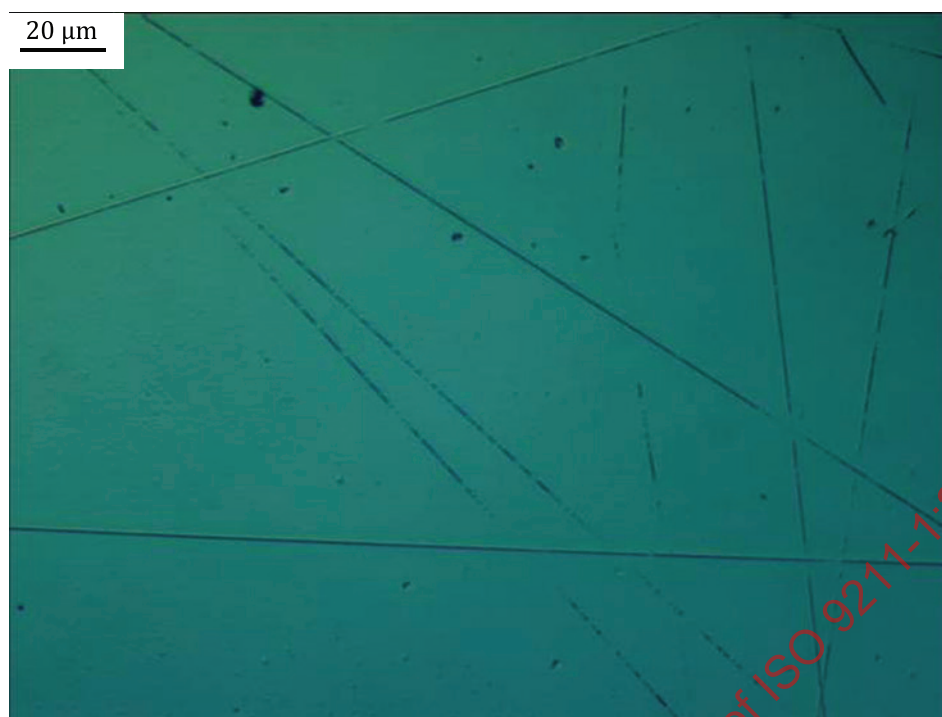


Figure A.6 — Scratches



Figure A.7 — Hairline scratch or sleek

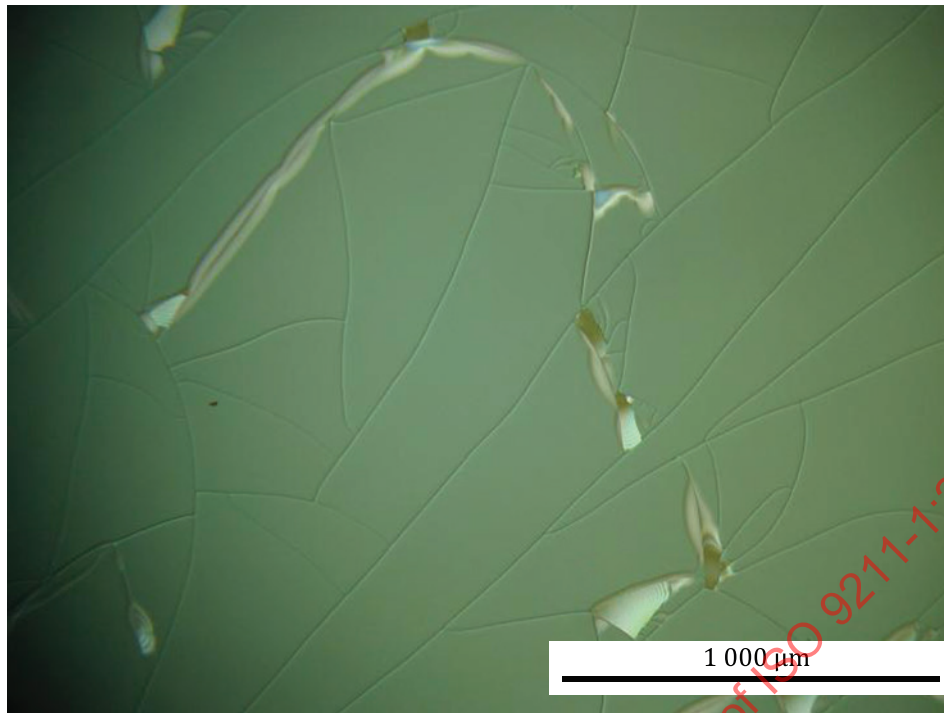


Figure A.8 — Crack

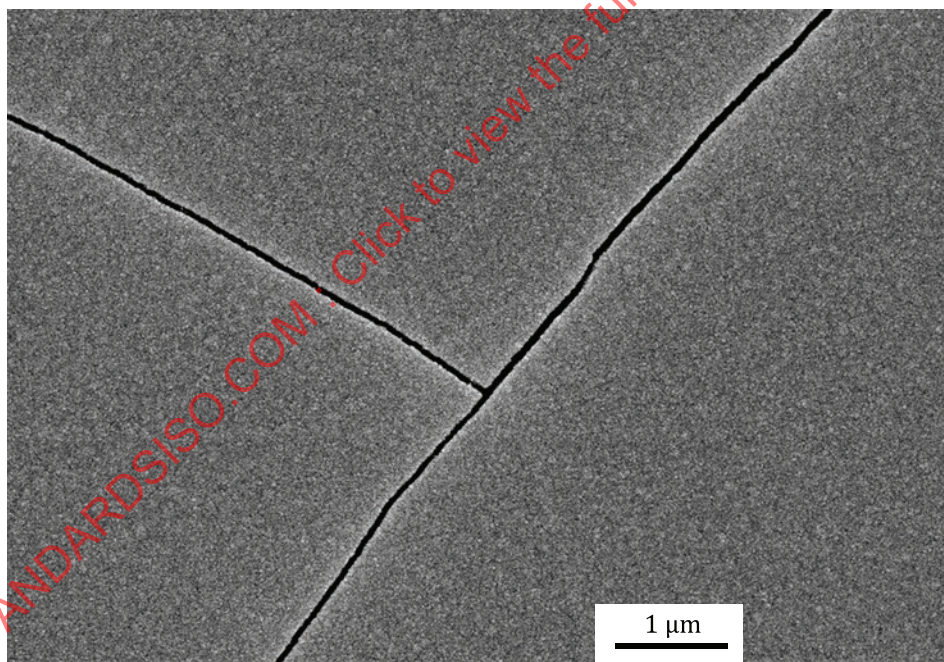


Figure A.9 — Crazing

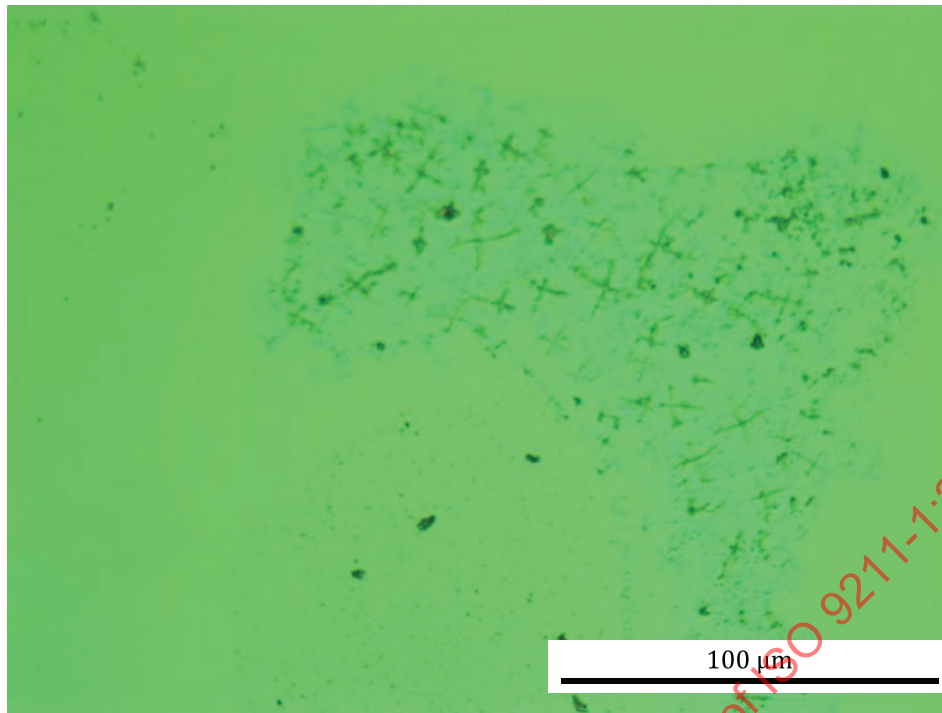


Figure A.10 — Stain



Figure A.11 — Abrasion