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**Optics and photonics — Optical  
materials and components —  
Characterization of optical materials  
used in the infrared spectral range  
from 0,78  $\mu\text{m}$  to 25  $\mu\text{m}$**

*Optique et photonique — Matériaux et composants optiques —  
Caractérisation des matériaux optiques utilisés dans la bande  
spectrale infrarouge de 0,78  $\mu\text{m}$  à 25  $\mu\text{m}$*

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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 172, *Optics and photonics*, Subcommittee SC 3, *Optical materials and components*.

This second edition cancels and replaces the first edition (ISO 11382:2010), which has been technically revised.

The main changes are as follows:

- update of [Clause 2](#) and Bibliography;
- update of [Table 1](#) and [Table 2](#).

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

Many standards for optical glass exist that are primarily used for the visible range, however, it is not easy to apply these standards directly to infrared materials.

Often, the properties of infrared materials are known with less certainty than those used in the visible range because the methods of measurements are different, incomplete or inaccurate.

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# Optics and photonics — Optical materials and components — Characterization of optical materials used in the infrared spectral range from 0,78 $\mu\text{m}$ to 25 $\mu\text{m}$

## 1 Scope

This document provides guidelines for the description of data sheets for infrared materials. It specifies the nomenclature and the properties of infrared materials which are reported on such data sheets. These data sheets do not necessarily contain information on every property identified in this document.

This document also specifies the parameters needed to characterize optical materials intended for use in the infrared spectral range from 0,78  $\mu\text{m}$  to 25  $\mu\text{m}$  and provides various methods to be used for measuring these parameters.

This document is applicable only to materials used in the manufacture of passive optical components. The properties of materials used in active applications (e.g. optoelectronics) are not taken into account.

Materials specified in this document can also transmit in other spectral domains (microwaves, visible or ultraviolet).

## 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 10110-18, *Optics and photonics — Preparation of drawings for optical elements and systems — Part 18: Stress birefringence, bubbles and inclusions, homogeneity, and striae*

ISO 12123:2018, *Optics and photonics — Specification of raw optical glass*

ISO 15368, *Optics and photonics — Measurement of reflectance of plane surfaces and transmittance of plane parallel elements*

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 12123, ISO 80000-7 and the following apply<sup>1)</sup>.

ISO and IEC maintain terminology 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

#### **regular transmittance**

ratio of the regularly transmitted part of the (whole) transmitted flux to the incident flux

1) These terms and definitions are consistent with those given in IEC 60050-845 and ISO/IEC Guide 98-3.

**3.2**

**regular reflectance**

specular reflectance

ratio of the regularly reflected part of the (whole) reflected flux to the incident flux

**3.3**

**absorptance**

ratio of the absorbed radiant flux to the incident flux

**3.4**

**scatter**

scatterance

ratio of the scattered radiant flux to the incident flux

**3.5**

**standard uncertainty**

uncertainty of the result of a measurement expressed as a standard deviation

**3.6**

**expanded uncertainty**

quantity defining an interval about the result of a measurement that may be expected to encompass a large fraction of the distribution of values that could reasonably be attributed to the measurand

## 4 Symbols and units

For the purposes of this document, the following symbols and units apply.

$d$  thickness of the sample, expressed in millimetres

$\alpha$  absorptance

$\delta$  scatter

$\lambda$  wavelength, expressed in micrometres

$\rho$  reflectance

$\tau$  transmittance

## 5 Nomenclature

### 5.1 General

The optical materials covered by this document shall be identified as follows:

- a) the name (see [5.2](#));
- b) the manufacturer reference (see [5.3](#));
- c) the material structure (optional) (see [5.4](#));
- d) the manufacturing process (see [5.5](#));
- e) a reference to this document, i.e. ISO 11382:2022.

### 5.2 Name

Either the trademark or the generic name (e.g. germanium or sapphire), followed by reference to the method of manufacture, shall be given in the nomenclature.

### 5.3 Manufacturer reference

A reference to the manufacturer shall be given in the nomenclature.

### 5.4 Material structure

If known, the type of the material structure shall be given, i.e. the following:

- amorphous material (e.g. glasses and some plastics);
- polycrystalline material;
- crystal (natural or synthetic);
- ceramics, etc.

### 5.5 Manufacturing process

The manufacturing process shall be given in the nomenclature; this description may be simplified (e.g. CVD instead of chemical vapour deposition). If a change in the manufacturing process modifies one or several properties of the material, another reference shall be used.

**NOTE** A great number of materials which transmit in the infrared spectral range exist in nature. However, due to their scarcity, small size, or impurity levels, the optical materials are usually manufactured or refined by industrial processes.

### 5.6 Form of nomenclature

The nomenclature shall be expressed in sequence, separated by dashes, as shown in the following examples.

EXAMPLE 1 Germanium – Manufacturer A – Monocrystalline n type – Zone fusion – ISO 11382:2022

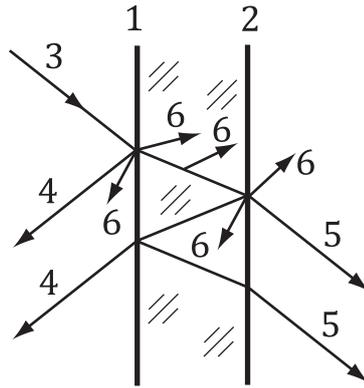
EXAMPLE 2 ZnS – Manufacturer B – Polycrystalline – Hot isostatic pressed – ISO 11382:2022

## 6 Optical properties

### 6.1 General

The methods for obtaining data should be reported. If the data are quoted from a reference, the reference document and publication data date shall be reported.

The material is assumed to be in the form of a plane-parallel element with optically polished surfaces 1 and 2, as shown in [Figure 1](#).



**Key**

- 1, 2 optically polished surfaces
- 3 incident light beam
- 4 reflected part
- 5 transmitted part
- 6 scattered part

**Figure 1 — Schematic of the light propagation through an element**

The light beam incident on the schema given in [Figure 1](#) is divided into

- a reflected part,
- a transmitted part,
- a scattered part, and
- an absorbed part.

If  $m$  donates a surface number, the light beam incident can be described by [Formulae \(1\)](#) to (3), as follows:

$$\tau_m + \rho_m + \alpha_m + \delta_m = 1 \tag{1}$$

$$\tau_t = \frac{\tau_1 \tau_i \tau_2}{1 - \tau_i^2 \rho_1 \rho_2} \text{ or } \tau_t = \frac{\tau_s^2 \tau_i}{1 - \tau_i^2 \rho_s^2} \tag{2) and (3)}$$

where

- $\tau_t$  is the transmittance of the element;
- $\tau_m$  is the regular transmittance of the surface,  $m$ ;
- $\tau_1$  is the regular transmittance of surface 1;
- $\tau_2$  is the regular transmittance of surface 2;
- $\tau_s$  is the regular transmittance of the surface,  $m$ , when surfaces 1 and 2 are identical;
- $\tau_{dm}$  is the scattered transmittance of the surface,  $m$ ;
- $\tau_i$  is the internal transmittance of the element;

$\rho_m$	is the regular reflectance of the surface, $m$ ;
$\rho_1$	is the regular reflectance of surface 1;
$\rho_2$	is the regular reflectance of surface 2;
$\rho_s$	is the regular reflectance of the surface, $m$ , when surfaces 1 and 2 are identical;
$\rho_{dm}$	is the scattered reflectance of the surface, $m$ ;
$\alpha_m$	is the absorptance of the surface, $m$ ;
$\delta_m = \rho_{dm} + \tau_{dm}$	is the total scatter of the surface, $m$ .

## 6.2 Transmittance

### 6.2.1 Specification to be provided

The measurement shall be made in accordance with ISO 15368.

The transmittance shall be measured at  $20_{-1}^{+3}$  °C. The standard thicknesses of the specimens shall be  $(2 \pm 0,1)$  mm,  $(5 \pm 0,1)$  mm or  $(10 \pm 0,2)$  mm.

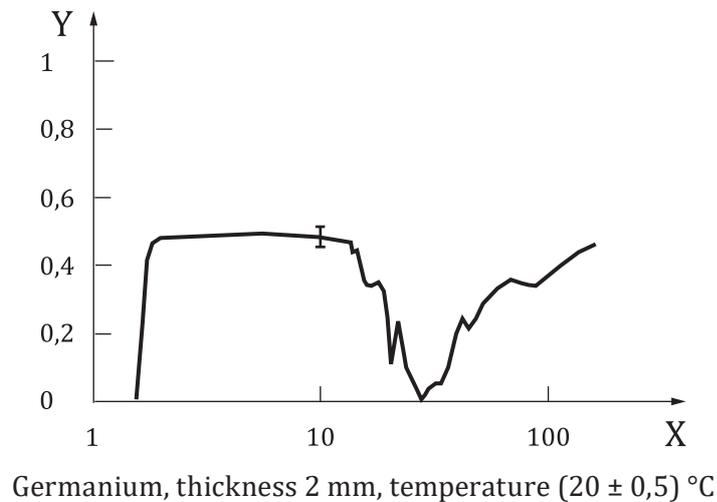
The transmittance shall be represented by a graph, with the wavelength (or wave number) as the X-axis, and the transmittance as the Y-axis. Uncertainty (e.g. standard uncertainty ( $\pm\sigma$ ) or expanded uncertainty ( $\pm k\sigma$ ) with  $k = 2$ ) for the transmittance shall be provided by error bars on the curves, or in a statement in the graph description.

The following shall be reported:

- the thickness of the sample (in the case of multiple curves, with suitable annotation, denoting different thicknesses should be on the same graph);
- the temperature of the piece during the measurement, with its uncertainty of measurement;
- the value of the parameters affecting the transmittance (e.g. resistivity for a semiconductor).

Unless otherwise reported, the incident beam is assumed to be normal to the surface and unpolarized.

An example is given in [Figure 2](#).

**Key**

X wavelength, μm  
Y transmittance

**Figure 2 — Example of transmittance**

### 6.2.2 Temperature dependence

The transmittance shall be measured over an appropriate range of temperatures, selected in a suitable manner to clearly show any temperature dependence. Graphs of this data shall be presented as described in [6.2.1](#).

The usual temperature range is  $-40\text{ °C}$  to  $+70\text{ °C}$ , but for specific applications, some materials may be used at cryogenic temperatures (50 K or 77 K), or at high temperatures ( $\leq 500\text{ °C}$  or  $\leq 700\text{ °C}$ ).

## 6.3 Absorption coefficient

### 6.3.1 General

The internal transmittance,  $\tau_i$ , is expressed in terms of an absorption coefficient,  $a$ , as calculated by [Formula \(4\)](#):

$$\tau_i = e^{-ad} \quad (4)$$

### 6.3.2 Specification to be provided (to be consistent with [6.5.2](#))

The values of the absorption coefficient,  $a$ , shall be reported, along with the uncertainty values, in the form of tables, including the following:

- wavelength (sampling shall be sufficient to show any significant spectral structure);
- temperature;
- direction of propagation (for anisotropic materials);
- specific parameters (e.g. resistivity for semiconductors).

## 6.4 Transmittance uniformity

### 6.4.1 General

Non-uniformity of transmittance may be due to numerous phenomena such as inclusions, bubbles, and local variations in the manufacturing process (e.g. incomplete annealing, local variation of composition).

### 6.4.2 Bubbles and inclusions

The symbolism of ISO 10110-18 is appropriate and shall be used. However, many infrared materials are opaque or scattering in the visible band, and the measurements are more complex. Experimental apparatus (e.g. those used for the Shadow method) shall be fitted with infrared detectors. In this case, the pixel elements of the apparatus shall be in accordance with the size of the minimum deflection sought.

### 6.4.3 Local variation of the manufacturing process

The detection of the deflection of light due to inhomogeneity of the material is limited by the sensitivity of the measurement apparatus (interferometer, densitometer, etc.).

The spatial resolution and photometric resolution of the apparatus used shall be reported. These two parameters are usually linked.

## 6.5 Refractive index

### 6.5.1 General

Theoretically, the refractive index,  $\tilde{n}$ , is a complex number, as calculated by [Formula \(5\)](#):

$$\tilde{n} = n + ik \quad (5)$$

where  $k$  is the extinction coefficient and related to the absorption coefficient,  $a$ , by [Formula \(6\)](#):

$$k = \frac{a\lambda}{4\pi} \quad (6)$$

When the absorption is negligible, the real part of this number,  $n$ , is termed the index of the material.

The refractive index depends on

- the wavelength,
- the direction of propagation (for anisotropic materials),
- the temperature, and
- other parameters, e.g. doping.

The refractive index varies between production batches and with the manufacturing method.

The nominal refractive index represents the average value of the range of values from the particular manufacturing process.

### 6.5.2 Specification reports to be provided

The refractive index shall be reported at  $20_{-1}^{+3}$  °C, with air as the external medium.

The nominal refractive index should be reported

- a) either in the form of a data table, as a function of wavelength, or
- b) in the form of one of the formulae of dispersion (e.g. Sellmeier formula).

The values of critical parameters shall be reported for

- the spectral range over which the formula is valid, and
- the maximum uncertainty over the spectral range.

The direction of propagation and polarization shall be reported for anisotropic materials.

### 6.6 Refractive index variation

The terms and definitions of ISO 10110-18 and ISO 12123 are appropriate and shall be used.

The value of the refractive index may vary between production batches.

Table 1 gives the tolerance limits for different classes of the refractive index variation.

Classes shall be defined as a function of the maximum difference between the refractive index and the nominal refractive index.

The refractive index should be defined at 4,00 μm or at 10,00 μm. When the material has little or no transmittance at one or other of the above wavelengths, the refractive index shall be measured at one or more wavelengths within the transmittance range, at integer values of the wavelengths, in micrometres.

Six classes are defined depending on the maximum difference between measured refractive index,  $n_{ms}$ , and the nominal refractive index,  $n_{nom}$ , as shown in Table 1.

**Table 1 — Tolerance limit for refractive index variation classes**

Grade ( $\lambda = 4 \mu\text{m}$ ) <sup>a</sup>	NP 0001	NP 0010	NP 0100	NP 0500	NP 1000	—
$ n_{ms} - n_{nom} $ <sup>b</sup>	≤0,000 01	≤0,000 1	≤0,001	≤0,005	≤0,01	>0,01
<sup>a</sup> Wavelength shall be reported for a specific case (e.g. 4 μm in the case shown).						
<sup>b</sup> $n_{ms}$ shall be measured under the same conditions (temperature, etc.), as specified for $n_{nom}$ .						

### 6.7 Dependence of the refractive index on temperature

The value  $dn/dT$  should be reported.

Generally, this value may vary with the wavelength. This value shall be reported for appropriate discrete wavelengths.

The limits of validity, and the uncertainty (standard uncertainty or expanded uncertainty) shall be reported.

Alternatively, a formula may be provided (as a function of wavelength and temperature).

### 6.8 Optical homogeneity (homogeneity of refractive index)

The terms of ISO 12123:2018, 4.6 are appropriate and shall be used.

The homogeneity of the refractive index across the volume of the material is important. It is assumed that the material temperature is uniform across the volume.

The homogeneity may depend on the size and the form of the piece.

Seven classes of index homogeneity are defined, depending on the variation,  $dn$ , inside the volume of the piece, as shown in [Table 2](#).

**Table 2 — Homogeneity of refractive index**

Grade	NH 0004	NH 0010	NH 0040	NH 0100	NH 0400	NH 1000	—
$dn$	$\leq 0,000\ 004$	$\leq 0,000\ 01$	$\leq 0,000\ 04$	$\leq 0,000\ 1$	$\leq 0,000\ 4$	$\leq 0,001$	$> 0,001$

## 6.9 Birefringence

### 6.9.1 Materials with natural birefringence

Many crystals exhibit double refraction, or birefringence.

In this case, specifications should be reported in a table with two columns:

- one for the ordinary index;
- the other for the extraordinary index.

The conditions (wavelength, direction of propagation, temperature, etc.) shall be reported.

### 6.9.2 Stress birefringence

Birefringence may occur in normally isotropic materials. It is the result of an internal stress and usually arises from the manufacturing process.

Birefringence produces a difference in the index of refraction in the material for light polarized parallel or perpendicular to the residual stress. This can affect the wave-front quality or optical path difference of the light transmitted by the optical element.

The optical path difference,  $\Delta s$ , between the two orthogonal polarizations of transmitted light over the thickness of the sample is a measure of the birefringence.

This is given by [Formula \(7\)](#):

$$\Delta s = dSK \quad (7)$$

where

$d$  is the thickness of the sample, expressed in mm;

$S$  is the residual stress, expressed in N/mm<sup>2</sup>;

$K$  is the difference in photoelastic constants, expressed in mm<sup>2</sup>/N.

NOTE ISO 10110-18 and ISO 11455 are also applicable to the stress birefringence.

## 6.10 Photoelastic constant

The coefficients of the tensor should be reported.

## 6.11 Dispersion

The dispersion should be reported.

## 7 Other properties

### 7.1 General

The following properties shall be reported on the data sheet. The methods for obtaining data and date should be reported. If the data is quoted from a reference, the reference document and publication date or measurement data date shall be reported.

### 7.2 Specific gravity

The specific gravity should be reported (water at 4 °C as the reference material).

### 7.3 Molecular weight

The molecular weight should be reported.

Units are not ordinarily specified for atomic or molecular weight.

NOTE "Molecular weight" is a unit-less quantity and approximately equals to the total number of protons and neutrons in the molecule.

### 7.4 Thermal properties

#### 7.4.1 Thermal conductivity

The thermal conductivity should be reported.

#### 7.4.2 Thermal expansion

The coefficients of linear thermal expansion should be reported.

#### 7.4.3 Specific heat

The specific heat should be reported.

#### 7.4.4 Melting temperature and softening temperature

The melting temperature at atmospheric pressure should be reported.

The softening temperature at atmospheric pressure should be reported, if applicable.

### 7.5 Hardness

The Knoop number should be reported.

### 7.6 Elastic modulus

The elastic modulus should be reported.

### 7.7 Maximum dimensions

The manufacturer shall report the following:

- a) a preferred shape;
- b) the maximum dimensions of the material that can be obtained with its own manufacturing process.