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Optics and photonics — Optical materials and components — Specification of chalcogenide glass used in the infrared spectrum

Optique et photonique — Matériaux et composants optiques — Spécification des verres de chalcogénure utilisés dans le spectre infrarouge

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Contents

Page

Foreword

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

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

This document applies to the specification of chalcogenide glass used in the infrared spectrum. Chalcogenide glass described in this document is transparent in the infrared region.

Chalcogenide glass has a wide range of transparency from the visible to the infrared wavelength region. This depends on chalcogenide chemical composition. The optical properties of chalcogenide glass can provide flexibility and further capability for IR optical system.

Nowadays, chalcogenide glass is used as a substitute material for traditional infrared materials like germanium, silicon or zinc selenide. The market for chalcogenide glasses is rapidly expanding. However, this new material is sometimes distributed without specifying its properties and qualities, which can confuse users. In consideration of the rapidly increasing of market for infrared application, the definition and standardization of chalcogenide glass for infrared optics are necessary.

Optics and photonics — Optical materials and components — Specification of chalcogenide glass used in the infrared spectrum

1 Scope

This document defines chalcogenide glass correctly from a chemical perspective and specifies basic characterization and reporting of optical properties of chalcogenide glass used in the infrared spectral range from 0,78 um to 25 um

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 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 17328, *Optics and photonics — Optical materials and components — Test method for refractive index of infrared optical materials*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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
glass
inorganic product, usually obtained after melting, cooling and annealing without crystallization; including the solid state glass before production and the glass strip obtained in production

[SOURCE: ISO 9802:2022, 3.2.1]

3.2
chalcogenide glass
glass (3.1) compound comprising of at least one chalcogen element (group 16 in the periodic table) with the exception of oxygen

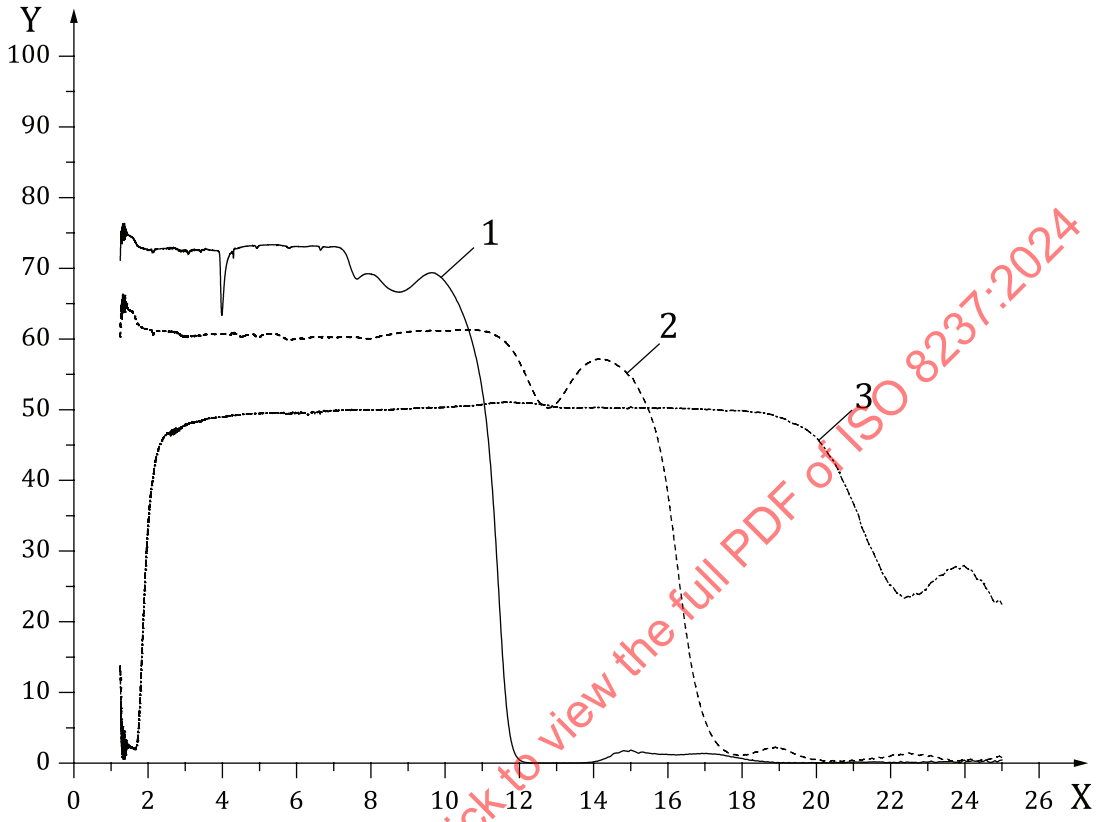
Note 1 to entry: The compositions used in chalcogenide glass are sulfur (S), selenium (Se) and tellurium (Te). Chalcogenide glass is also sometimes called sulfide glass, selenium glass or telluride glass depending on the most abundant composition.

Note 2 to entry: Polonium (Po) and livermorium (Lv) are not typically considered for chalcogenide compositions.

3.3
regular transmittance
ratio of the regularly transmitted part of the (whole) transmitted flux to the incident flux

[SOURCE: ISO 11382:2010, 3.1]

Note 1 to entry: Typical transmittance spectra of glass is shown in Figure 1.



Key

X wavelength, λ, in micrometre
Y transmittance, τ_r, in percent
1 transmittance spectra of sulfide glass
2 transmittance spectra of selenide glass
3 transmittance spectra of telluride glass

Figure 1 — Typical transmittance spectra of sulfide (S) glass, selenide (Se) glass and telluride (Te) glass

3.4
internal transmittance
ratio of the radiant flux to the incident radiant flux of a collimated beam that passes, at normal incidence, through a plane parallel polished plate, excluding reflection losses at the surfaces

$$\tau_i = \frac{-(\rho - 1)^2 + \sqrt{\rho^4 - 4\rho^3 + 4\rho^2\tau_r^2 + 6\rho^2 - 4\rho + 1}}{2\rho^2\tau_r}$$

where

τ_r is regular transmittance;

τ_i is internal transmittance;

ρ is reflectance.

[SOURCE: ISO 12123:2018, 3.12]

3.5
optical homogeneity
gradual refractive index variation within a single piece of optical glass given by the difference between the maximum and minimum values of the refractive index within the optical glass

[SOURCE: ISO 12123:2018, 3.16]

3.6
striae
short spatial range variation of refractive index in glass with typical spatial extent from below one millimetre up to several millimetres

[SOURCE: ISO 12123:2018, 3.17]

3.7
bubble
gaseous void in the bulk optical material of generally circular cross section

Note 1 to entry: Bubbles and solid inclusions are treated the same in assessing the quality of optical glass.

[SOURCE: ISO 12123:2018, 3.19]

3.8
inclusion
localized bulk material imperfections

EXAMPLE Bubbles, striae knots, small stones, sand and crystals.

Note 1 to entry: These terms are also applicable in the given wavelength range.

[SOURCE: ISO 12123:2018, 3.18]

4 Symbols and units

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

λ wavelength, expressed in micrometres

n_λ refractive index at wavelength λ

P relative partial dispersion

τ_r spectral regular transmittance of the specimen

τ_i internal transmittance

5 Optical properties

5.1 General

As with general optical glass, the composition of chalcogenide glass determines its optical properties. In addition to the measurement and reporting method of the basic properties of transmittance, refractive

index, and relative partial dispersion which are necessary to consider the use of chalcogenide glass in optical systems, this section defines temperature dependence of the refractive index also.

5.2 Transmittance

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

— thickness of the sample (in the case of multiple curves, with suitable annotation, denoting different thicknesses should be on the same graph);

— temperature of the piece during the measurement, with its uncertainty.

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

The spectral regular transmittance, τ_r, shall be measured in accordance with ISO 15368.

NOTE Some chalcogenide glasses have transmittance that varies with temperature.

5.3 Refractive index

The measurement shall be performed at 20^{+3}_{-1} °C, with air as the external medium. The spectral range to be measured should be selected according to the transmission range of each glass.

The refractive index shall be reported either in the form of a data table as a function of wavelength or in a form of dispersion formulae (e.g. Sellmeier formula). Measurement method, conditions and uncertainty shall be reported.

The refractive index, n_λ, shall be measured in accordance with ISO 17328.

5.4 Temperature dependence of the refractive index

The temperature dependence of the refractive index $\Delta n_\lambda/\Delta T$ should be measured and reported in accordance with ISO 6760-1.

5.5 Relative partial dispersion

Difference of refractive indices, $n_{\lambda_1} - n_{\lambda_2}$, between two wavelengths λ_1 and λ_2 related to another partial dispersion, $n_{\lambda_3} - n_{\lambda_4}$, between two other wavelengths λ_3 and λ_4, represented by

$$P_{\lambda_1\lambda_2\lambda_3\lambda_4} = \left(n_{\lambda_1} - n_{\lambda_2}\right) / \left(n_{\lambda_3} - n_{\lambda_4}\right)$$

The order of the wavelength for P shall be $\lambda_1 < \lambda_2 \leq \lambda_3 < \lambda_4$. This is a mutually agreed upon order by the manufacturer and customer.

6 Tolerances

6.1 General

Since chalcogenide glass is a multi-component glass, compositional inhomogeneities can occur depending on manufacturing methods and process skills, which can lead to variations in optical properties.

6.2 Refractive index variation

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

The refractive index variation $\left|n_{\lambda,\mathrm{ms}} - n_{\lambda,\mathrm{nom}}\right|$ is defined as the difference between measured refractive index, $n_{\lambda,\mathrm{ms}}$, and the nominal refractive index, $n_{\lambda,\mathrm{nom}}$. The nominal refractive index means the value declared in the catalogue or data sheet.

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, but is not limited to this. 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, $n_{\lambda,\mathrm{ms}}$, and the nominal refractive index, $n_{\lambda,\mathrm{nom}}$, as shown in Table 1.

Table 1 — Tolerance limit for refractive index variation classes

Grade (λ = 4 µm)[a]	NP 0001	NP 0010	NP 0100	NP 0500	NP 1000	—
$\left\|n_{\lambda,\mathrm{ms}} - n_{\lambda,\mathrm{nom}}\right\|$ [b]	≤0,000 01	≤0,000 1	≤0,001	≤0,005	≤0,01	>0,01

[a] Wavelength shall be reported for a specific case (e.g. 4 µm in the case shown).

[b] $n_{\lambda,\mathrm{ms}}$ shall be measured under the same conditions (temperature, etc.), as specified for $n_{\lambda,\mathrm{nom}}$.

6.3 Optical homogeneity (homogeneity of refractive index dn_λ)

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

Table 2 provides the tolerance limits for the different classes of optical homogeneity. Optical homogeneity should be measured according to ISO 19740 for the infrared wavelength region. The optical homogeneity should be measured according to ISO 17411 for the visible wavelength region.

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

Seven classes are defined for optical homogeneity, depending on the variation dn_λ inside the volume of the piece, as shown in Table 2.

Table 2 — Optical homogeneity

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

6.4 Striae

The terms of ISO 12123:2018, 4.7 are appropriate and shall be used.

Striae are generally detected by means of the shadowgraph method using comparison standards. The wavefront deviation of the comparison standard is certified in advance using an interferometer set-up.

Table 3 gives the tolerance limits for the different classes of striae.

NOTE Striae can be measured in accordance with ISO 19741 and classified by referring to ISO 10110-18.

Table 3 — Striae wavefront deviation tolerances

Grade	Traditional striae grades	Striae wavefront deviation tolerance limit per 15 mm path length (lambda)	Generally applicable for
—	D	>0,5	raw glass
IRSW 05	C	≤0,5	
IRSW 02	B	≤0,2	partial volumes of the raw glass
IRSW 007	A	≤0,07	
NOTE 1 The traditional striae grades are not simply synonyms for the IRSW grades. The traditional striae grades apply to an entire piece of glass of any size. They are equivalent to the IRSW grades only when the path length through the piece is exactly 15 mm.			
NOTE 2 The striae wavefront deviation varies to the measurement wavelength.			

Striae are highly directionally dependent. If striae are perceived during a test, they are usually no longer detectable when inspected in a direction perpendicular to the original test direction.

Striae in optical chalcogenide glasses are in general band-like, therefore the striae wavefront deviation is dependent on the sampling thickness to a certain extent. In general, the raw glass parts are inspected through the total thickness. Since the thickness of the finished parts is in most cases only a fraction of the initial thickness, the striae wavefront deviation will also be much lower. Therefore, the reference thickness of 15 mm is introduced to specify striae quality of general purpose chalcogenide glass.

6.5 Bubbles and inclusions

The terms of ISO 12123:2018, 4.8 are appropriate and shall be used.

Material imperfection value and maximum permissible cross section of inclusion (mm^2) should be used to define the bubble and inclusions within chalcogenide glasses.

Five classes of bubbles and inclusions are defined, depending on the cross section or numbers, as shown in Table 4 and Table 5.

NOTE Bubbles and inclusions can be measured in accordance with ISO 19742 and classified by referring to ISO 10110-18.

Table 4 — Bubbles and inclusions: maximum permissible cross section

Grade	IRIC 1	IRIC 2	IRIC 4	IRIC 10	—
Maximum permissible cross section (mm^2 per 100 cm^3)	1	2	4	10	>10

Table 5 — Bubbles and inclusions: maximum number

Grade	IN 010	IN 030	IN 070	IN 140	—
Maximum number (per 100 cm^3)	10	30	70	140	>140

7 Data sheet contents

The data sheet of a chalcogenide glass should contain the following information:

a) a reference to this document, i.e. ISO 8237:2024;

b) manufacturer of the chalcogenide glass and chalcogenide glass type;

c) spectral transmittance, τ_r;

d) refractive index and refractive index tolerance grade;