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Optics and photonics — Specification of raw optical glass

Optique et photonique — Spécification d'un verre d'optique brut

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Foreword

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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).

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).

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.

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

This third edition cancels and replaces the second edition (ISO 12123:2010), which has been technically revised.

The main changes compared to the previous edition are as follows:

a) definition of relative partial dispersion and its deviation from normal line and definition of internal transmittance have been added;

b) grade abbreviations at all tolerances in Clause 4 have been added;

c) all abbreviations have been written with two capital letters with relation to characteristics' names;

d) in 4.6, an indication for required minimum aperture has been added;

e) in 4.7, striae indication for two and three perpendicular inspection directions has been added;

f) for partial dispersion and its deviation from normal line, the following has been added: dispersion data for standard crown and flint glass for normal environment, general formula for normal lines for the relative partial dispersions for any wavelength pairs, examples for six specific line pairs in Clause 5 and a calculation method and data for calculating dispersion data at temperatures other than 20 °C (see A.3);

g) in Clause 6, Example 1 for specification of optical raw glass with tolerances grades has been introduced and extended by adding a second case;

h) in Clause 6, Example 2 has been added and illustrates lens element specification from element over pressing to raw glass specification;

i) Tables have been renumbered.

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

Raw optical glass comes as strip glass, pressings block glass or large castings. Its characteristics are widely the same as those for optical elements such as lenses and prisms. However, the tolerance limits and their applicability are not the same. This comes from the fact that as a rule the raw optical glass delivery forms are much larger than the optical elements which will be made out of them. A glass strip of 280 mm length, 160 mm width and 40 mm thickness renders hundreds of small lenses. Simply transferring the glass requirements on the single lens to the total strip will lead to confusion or to severe over-specification. Required complete absence of bubbles and inclusions in a lens cannot mean the same requirement on the strip. A high homogeneity requirement for a small lens extended to the total strip without restricting it to the intended lens diameter will result in a uselessly narrow tolerance. It is even detrimental since it will lead to unnecessary high costs or even inability of the glass manufacturer to deliver the material requested.

The absolute refractive index and the Abbe number as a measure of dispersion apply for the raw optical glass formats as well as for the optical elements to be made out of them. Two variations of the refractive index have to be distinguished clearly: the first is the variation among different pieces of a common delivery lot and the second is the limited variation within a single piece, which is called optical homogeneity. The variation within a delivery lot is a symmetric tolerance with the test certificate value of the refractive index as reference. The optical homogeneity has no such practically determinable reference value. It is given as a span width (peak-to-valley) tolerance.

Refering to the size of the optical elements to be made out of the raw glass items will expedite offers and delivery. This holds especially for all homogeneity characteristics (refractive index variation: optical homogeneity, short-range refractive index variation: striae, material contiguity: bubbles and inclusions and refractive index polarization homogeneity: stress birefringence). In general, homogeneity tolerances increase requirements on quality strongly.

This edition introduces grade denominations for tolerance limits for the main properties of optical raw glass. The characteristics colour code and UV cut-off edge are different possibilities to describe position and slope of the UV-transmission edge of optical glasses.

Furthermore, this edition introduces definitions, reference formulae and data needed for calculating the deviation of the relative partial dispersion from the normal line. This quantity serves to value the suitability of optical glasses for colour aberration correction beyond achromatic correction of only two colours. The key element is the definition of two reference dispersion curves, one of a standard crown and one of a standard flint glass. Based on these curves normal line parameters can be derived for partial dispersions of any two wavelengths between 365 nm and 1 014 nm. In order to support the main target of improving comparison of glass types from different vendors examples for normal lines are given for six wavelength pairs covering the spectral range as specified above. The dispersion data of the reference glass types are valid for the temperature 20 °C. The annex contains the method for calculating the dispersion data for temperatures different from 20 °C.

The Annex of the document gives some explanations and recommendations for applying the document in ways which avoid over-specification and its unfavourable consequences.

This document was prepared in coordination with the preparation of ISO 10110-18, which provides a notation for the material tolerances of finished optical elements.

Optics and photonics — Specification of raw optical glass

1 Scope

This document gives rules for the specification of raw optical glass. It serves as a complement to the ISO 10110 series, which provides rules specifying finished optical elements. Since raw optical glass can be quite different in shape and size from the optical elements, its specification also differs from that of optical elements.

This document provides guidelines for the essential specification characteristics of raw optical glass in order to improve communication between glass suppliers and optical element manufacturers. For specific applications (e.g. lasers, the infrared spectral range), specifications based on this document need supplements.

While the intent of this document is to address the specific needs of raw optical glass, many of the parameters and characteristics are common to other optical materials, which are not necessarily glass. While this document can be used for non-glass materials, the user is informed that only optical glass has been considered in the development of this document, and other materials can have issues, which have not been taken into consideration.

NOTE Additional information on how to translate optical element specifications into raw optical glass specifications is given in Annex A.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions 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 http://www.electropedia.org/

3.1
refractive index
n
ratio of the velocity of the electromagnetic waves at a specific wavelength in a vacuum to the velocity of the waves in the medium

Note 1 to entry: See ISO 7944.

Note 2 to entry: For practical reasons, this document refers to the refractive index in air.

3.2
principal refractive index
refractive index in the middle range of the visible spectrum commonly used to characterize an optical glass

Note 1 to entry: This principal refractive index is usually denoted as n_d, the refractive index at the wavelength 587,56 nm, or n_e, the refractive index at the wavelength 546,07 nm.

Note 2 to entry: The specific values for different glass types refer to standard environmental conditions (20 °C and 1 013 hPa according to ISO 1[1]). For all other temperatures and pressures, the specific temperature and pressure of interest shall be indicated.

3.3
refractive index variation
maximum difference of refractive index between samples of optical glasses

3.4
dispersion
measure of the change of the refractive index with wavelength

3.5
partial dispersion
difference of refractive index $n_{\lambda 1} - n_{\lambda 2}$ between two wavelengths λ_1 and λ_2

EXAMPLE $n_F - n_C$; $n_F' - n_C'$

n_F and n_C are the refractive indices at wavelengths 486,13 nm and 656,27 nm;

and n_F' and n_C' are the refractive indices at wavelengths 479,99 nm and 643,85 nm.

$n_F - n_C$ frequently serving as reference it is often called principal partial dispersion.

3.6
relative partial dispersion
difference of refractive index $n_{\lambda 1} - n_{\lambda 2}$ 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

$$P_{\lambda 1,\lambda 2,\lambda 3,\lambda 4} = (n_{\lambda 1} - n_{\lambda 2}) / (n_{\lambda 3} - n_{\lambda 4})$$

EXAMPLE $P_{g,F,F,C} = (n_g - n_F) / (n_F - n_C) = P_{g,F}$

n_g is the refractive index at wavelength 435,83 nm.

If related to the principal partial dispersion, $n_F - n_C$ indices for λ_1 and λ_2 are usually omitted.

3.7
Abbe number
most common characterization of the dispersion of optical glasses

EXAMPLE 1 The Abbe number for the d-line is defined as

$$v_d = \frac{(n_d - 1)}{(n_F - n_C)}$$

where

n_F is the refractive index at wavelength 486,13 nm;

n_C is the refractive index at wavelength 656,27 nm.

EXAMPLE 2 The Abbe number for the e-line is defined as

$$v_e = \frac{(n_e - 1)}{\left(n_{F'} - n_{C'}\right)}$$

where

n_F' is the refractive index at wavelength 479,99 nm;

n_C' is the refractive index at wavelength 643,85 nm.

3.8
glass type
letter/number designation used in the manufacturer's catalogue to designate or characterize the glasses offered

Note 1 to entry: An alphanumeric designation is the manufacturer's option and is usually a proprietary trade name, and therefore indeterminate. For example, borosilicate crown glass is designated N-BK by one manufacturer, but S-BSL and BSC by others.

Note 2 to entry: An alternative way to specify a glass type is the glass code. It is a six-digit number and refers to the optical position of the individual glass types. The first three digits refer to the refractive index n_d, the second three digits to the Abbe number v_d. For N-BK7 e.g. it is 517642. This glass code, however, does not denominate a glass type unequivocally. The same glass code can be valid for glass types of very different chemical compositions and hence other properties can differ also very significantly.

3.9
deviation of the relative partial dispersion
glass type specific distance of the relative partial dispersion $P_{\lambda1,\lambda2}$ (glass type) from that of the normal line $P_{\lambda1,\lambda2}$ (normal line)

$$\Delta P_{\lambda1,\lambda2}\ (\text{glass type}) = P_{\lambda1,\lambda2}\ (\text{glass type}) - P_{\lambda1,\lambda2}\ (\text{normal line})$$

$$\Delta P_{\lambda1,\lambda2}\ (\text{glass type}) = P_{\lambda1,\lambda2}\ (\text{glass type}) - (\mathrm{a}_{\lambda1,\lambda2} + \mathrm{b}_{\lambda1,\lambda2} \cdot v_\mathrm{d})$$

The line parameters $\mathrm{a}_{\lambda1,\lambda2}$ and $\mathrm{b}_{\lambda1,\lambda2}$ define the normal line

$$\Delta P_{\lambda1,\lambda2}\ (\text{normal line}) = \mathrm{a}_{\lambda1,\lambda2} + \mathrm{b}_{\lambda1,\lambda2} \cdot v_\mathrm{d}$$

for each partial dispersion.

Note 1 to entry: They are calculated from the partial dispersion/Abbe number combinations of a standard crown and a standard flint glass type.

Note 2 to entry: The deviation of the relative partial dispersion is a measure how suitable a glass type is for the correction of colour aberrations in imaging.

3.10
transmittance
ratio of the transmitted radiant flux to the incident radiant flux of a collimated, monochromatic beam that passes, at normal incidence, through a plane parallel polished plate

3.11
spectral transmittance
measure of the variation of the transmittance with wavelength

3.12
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

3.13
spectral internal transmittance
measure of the variation of the internal transmittance with wavelength

3.14
UV cut-off edge
UVC 80/10
position and the slope of the transmittance cut-off edge in the short wavelength range and given by the wavelengths at 80 % and 10 % internal transmittance

3.15
colour code
CC
position and slope of the transmittance cut-off edge in the short wavelength range, given by the wavelengths at 80 % and 5 % transmittance including reflection losses

3.16
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

Note 1 to entry: Interferometric inspection records only lateral relative refractive index changes within the measured aperture accumulated over the glass thickness and with higher order than linear. For changes along the sight axis and linear changes across the aperture it is insensitive. Such inspection is not fully in accordance with the definition of optical homogeneity but suitable for almost all applications except for very thick or large glass pieces.

3.17
striae
short spatial range variation of refractive index in glass with typical spatial extent from below one millimetre up to several millimetres

3.18
inclusion
localized bulk material imperfections

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

3.19
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.

3.20
stress birefringence
birefringence caused by residual stresses within the glass, generally as a result of different cooling histories of different partial volumes of a given piece of glass during the forming and/or annealing process, and producing an optical path difference between the ordinary and extraordinary rays for plane polarized light passing through the glass

Note 1 to entry: The optical path length difference is proportional to the magnitude of mechanical stress.

4 Tolerances

4.1 Principal refractive index

The preferred tolerance ranges for the principal refractive index (Grade denomination NP) are given in Table 1.

