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Optics and photonics — Preparation of drawings for optical elements and systems —

Part 18: Stress birefringence, bubbles and inclusions, homogeneity, and striae

Optique et photonique — Indications sur les dessins pour éléments et systèmes optiques —

Partie 18: Biréfringence sous contrainte, bulles et inclusions, homogénéité, et stries

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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).

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).

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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 1, *Fundamental standards*.

This first edition of ISO 10110-18 cancels and replaces ISO 10110-2:1996, ISO 10110-3:1996 and ISO 10110-4:1997 which have been merged into one document and technically revised.

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

a) additional notation defined for the indication code to directly specify the raw material for a finished part,

b) wavefront deviation method added for specifying limits to acceptable striae,

c) bubble concentration rule adjusted to count only maximum size bubbles,

d) multi-directional notation added to striae specification, and

e) focus term notation added to homogeneity specification.

A list of all the parts in the ISO 10110 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 ISO 10110 series is composed of separate parts. It standardizes drawing indications for optical elements and systems. This document (Part 18) standardizes drawing indications for the tolerancing of material imperfections.

Material imperfections require tolerances because they can degrade the quality of an optical part. This document provides notations for material imperfections in optical elements. This includes the specification of a tolerance for stress birefringence, bubbles and inclusions, refractive index homogeneity, and striae. It includes the notations and grades formerly described in ISO 10110-2, ISO 10110-3, and ISO 10110-4, and provides complete backward compatibility to drawings developed using those standards.

A drawing notation standard, such as this document for specifying all optical material tolerances, should accommodate all common specification methods to allow broad adoption and application. In some cases, material tolerances are specified on the final part, and in other cases material tolerances are specified on the raw material or blank used to make the final part.

Even on a single part, different tolerances may be specified and controlled in different ways. For example, it might be desirable to specify the bubbles and inclusions of a finished doublet assembly in addition to a specification on the individual elements. Additionally, for that same doublet, it might be prudent to specify raw material tolerances and accept the manufacturer's material quality certifications for stress birefringence, refractive index homogeneity and striae, which are much more difficult to validate on a finished part or assembly.

In this document, every effort has been made to provide flexibility in the notation to allow the materials to be specified in the most sensible means for the given application. In each case the user is allowed to either specify the material imperfection tolerance for the finished part, using the "0/", "1/", and "2/" notations, or to specify the quality of the material blank used in the manufacture of the part, using the "00/", "01/" and "02/" notations. If the specification is intended to apply to the finished assembly, the notations "10/", "11/", and "12/" are used.

Optics and photonics — Preparation of drawings for optical elements and systems —

Part 18: Stress birefringence, bubbles and inclusions, homogeneity, and striae

1 Scope

This document specifies the indication of tolerances for four categories of imperfections within optical materials — stress birefringence, bubbles and inclusions, homogeneity, and striae — in the ISO 10110 series, which standardizes drawing indications for optical elements and systems.

Tolerances are applied either to a finished optical part, a finished system of optical parts, or to the raw material used to manufacture an optical part.

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 9802, *Raw optical glass — Vocabulary*

ISO 10110-1, *Optics and photonics — Preparation of drawings for optical elements and systems — Part 1: General*

ISO 10110-11, *Optics and photonics — Preparation of drawings for optical elements and systems — Part 11: Non-toleranced data*

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

ISO 14999-4:2015, *Optics and photonics — Interferometric measurement of optical elements and optical systems — Part 4: Interpretation and evaluation of tolerances specified in ISO 10110*

3 Terms and definitions

For the purposes of this document, the terms and definitions of ISO 9802 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 http://www.electropedia.org/

3.1 Terms for stress birefringence

3.1.1
birefringence
variation of the refractive index with the orientation of polarization inside optical materials

3.1.2
stress birefringence
birefringence caused by mechanical stress within the optical material

Note 1 to entry: The formula relating the stress optical constant and stress birefringence is given in Annex A.

3.2 Terms for bubbles and inclusions

3.2.1
bubble
gaseous void, of generally circular cross section, in the bulk material

3.2.2
inclusion
localized bulk material imperfection including, but not limited to, bubbles, striae, knots, small stones, sand and crystals

3.2.3
grade number of a bubble or inclusion
unitless numeric label derived from a value in an R5 Renard sequence and specifying the square root of a projected area

Note 1 to entry: The grade number can be interpreted as an equivalent size, which is the approximate diameter of a circle that contains the specified area. The actual diameter of the circle is nearly 13 % larger than indicated by the grade number when units of linear dimension are appended.

3.2.4
negligible bubble or inclusion
bubble or inclusion whose grade number is 16 % of the maximum permissible grade or less

3.3 Terms for homogeneity and striae

3.3.1
homogeneity
gradual variation of the refractive index within a single piece of optical material

3.3.2
striae
short spatial range variation of refractive index with typical spatial extent from below one millimetre up to several millimetres

4 Specification of raw material and finished assemblies

4.1 Raw material

By prefixing the digit zero “0” to any of the indication codes, e.g. “00/”, “01/”, or “02/” rather than “0/", "1/”, or “2/”, the designer directs the specification to the raw material rather than to the finished part. Unless otherwise noted, this shall mean that the manufacturer’s quality certifications for the raw material that was used to manufacture the part will be accepted as proof that the part itself is in accordance with the specification.

ISO 12123 on raw optical glass defines specifications and quality grades for raw optical glass materials that shall be used whenever possible, even when tolerancing finished components.

4.2 Finished assemblies

By prefixing the digit one “1” to any of the indication codes, e.g. “10/”, “11/”, or “12/” rather than “0/”, “1/”, or “2/”, the designer directs the specification to a finished assembly of components rather than to a single component in the assembly.

5 Stress birefringence

5.1 Principle of specification

Stress birefringence is the optical path difference (OPD), in nanometres, between orthogonal polarizations of a light beam as it propagates one centimetre through the material (nanometres per centimetre).

NOTE Guidance for typical tolerances for stress birefringence for some applications is given in Annex B.

5.2 Indication in drawings

5.2.1 Indication codes

The indication code for stress birefringence in the finished part is "0/". The indication code for stress birefringence in the raw material is "00/" and for a finished assembly is "10/".

5.2.2 Structure of the indication

0/*A* or 00/*A* or 10/*A*

where *A* is the maximum allowable OPD in nm/cm.

5.3 Examples of indications for stress birefringence

EXAMPLE 1 0/2

The stress birefringence allowed in the finished part shall be less than or equal to 2 nm/cm.

EXAMPLE 2 00/20

The stress birefringence of the raw material used to manufacture the part shall be less than or equal to 20 nm/cm.

EXAMPLE 3 10/20

The stress birefringence in a finished assembly shall be less than or equal to 20 nm/cm.

6 Bubbles and inclusions

6.1 General

Bubble is used as the generic term for bubbles and/or inclusions, unless otherwise indicated.

6.2 Principle of specification

Specify the maximum size grade of a permissible bubble. Specify the maximum number of maximum grade bubbles. Control the total accumulated area obscured by all allowed bubbles.

Standard bubble grades are defined in Table 1. They were derived by rounding the values of a Renard sequence (R5) of size.

Table 1 — Standard bubble grades

Grade Number no units	Size (square root of area) mm	Area mm^2
0,006[a]	0,006[a]	$3{,}60 \times 10^{-5}$ [a]
0,010[a]	0,010[a]	$1{,}00 \times 10^{-4}$ [a]
0,016[a]	0,016[a]	$2{,}6 \times 10^{-4}$ [a]
0,025[a]	0,025[a]	$6{,}25 \times 10^{-4}$ [a]
0,040	0,040	$1{,}60 \times 10^{-3}$
0,063	0,063	$3{,}97 \times 10^{-3}$
0,10	0,10	$1{,}00 \times 10^{-2}$
0,16	0,16	$2{,}56 \times 10^{-2}$
0,25	0,25	$6{,}25 \times 10^{-2}$
0,40	0,40	$1{,}60 \times 10^{-1}$
0,63	0,63	$3{,}97 \times 10^{-1}$
1,0	1,0	$1{,}00 \times 10^{0}$
1,6	1,6	$2{,}56 \times 10^{0}$
2,5	2,5	$6{,}25 \times 10^{0}$
4,0	4,0	$1{,}60 \times 10^{1}$

[a] Bubbles smaller than 0,030 mm equivalent size are not typically relevant to the specification of raw optical glass.

NOTE Annex C contains guidance for typical specifications in several applications.

6.3 Indication in drawings

6.3.1 Indication codes

The indication code for bubbles in the finished part is “1/”. The indication code for bubbles in the raw material is “01/”. The indication code for bubbles throughout a finished assembly is “11/”.

6.3.2 Structure of the indication

$1/N \times A$ or $01/N \times A$ or $11/N \times A$

where

A is the grade number of the largest permissible bubble;

N is the maximum permissible number of largest permissible bubbles;

× is the multiply symbol to separate and relate N and A.

6.4 Accumulation rule

The sum of the projected areas of all bubbles with grade numbers less than or equal to A and greater than 0,16 A shall not exceed

$N \times A^2$ mm^2

where

N is the maximum number of the maximum size bubble that is indicated in the specification;

A^2 is the square of the grade number of the largest permissible bubble.

The accumulation rule allows more bubbles of smaller sizes, but their summed cross sectional areas shall remain below the maximum total areal limit established by the indicated specification.

6.5 Concentration rule

Concentrations of bubbles are not allowed.

A concentration occurs when more than 20 % of the number of allowed maximum grade bubbles is found in any 5 % sub-area of the test region. The 5 % sub-area shall have a similar form as the test region.

If the total number of allowed bubbles is less than 10, then a concentration occurs when two or more bubbles of allowed maximum grade fall within a 5 % sub-area of the test region.

For any bubbles with a grade of one to three grades smaller (down to 0,16 A) than the maximum allowed grade and within 5 % of the test region, accumulate the grade numbers to find the equivalent number of bubbles of maximum grade, rounding up. Then evaluate as described for maximum grade bubbles.

6.6 Examples of indications for bubbles

EXAMPLE 1 1/1 × 0,25

The largest permissible grade number of any bubble in the finished part is 0,25. The sum of the projected areas of all bubbles less than or equal to grade number 0,25 and greater than grade number 0,04 — which is 0,16 × 0,25 — shall be less than or equal to 0,062 5 mm^2.

EXAMPLE 2 01/3 × 0,5

The largest permissible grade number of any bubble in the raw material used to manufacture the part is 0,5. The maximum allowed number of maximum size bubbles is 3. The sum of the projected areas of all bubbles less than or equal to grade number 0,5 and greater than grade number 0,08 — which is 0,16 × 0,5 — shall be less than or equal to 0,75 mm^2.

EXAMPLE 3 11/1 × 0,25

The largest permissible grade number of any bubble throughout a finished assembly is 0,25. The sum of the projected areas of all bubbles less than or equal to grade number 0,25 and greater than grade number 0,04 — which is 0,16 × 0,25 — shall be less than or equal to 0,062 5 mm^2.

7 Homogeneity and striae

7.1 General

The two different specifications for permissible homogeneity and striae imperfections appear under the same indication code and are separated by a semicolon. Within the indication, the specification for homogeneity precedes the specification for striae. The basic specification may be modified with a focus term for homogeneity and a multi-directional term for homogeneity or striae.

7.2 Indication in drawings

7.2.1 Indication codes

The indication code for homogeneity and striae is “2/” for the finished part, “02/” for the raw material used to manufacture the finished part, or “12/” for a finished assembly.

7.2.2 Structure of the indication

Basic structure of the indication:

2/*A*; *B* or 02/*A*; *B* or 12/*A*; *B*

Standard quality classes for *A* are defined in Table 2. Standard quality classes for *B* are defined in Table 3 and Table 4.

Optional Focus term, "–F", added to the indication for homogeneity:

2/*A* – F; *B* or 02/*A* – F; *B* or 12/*A* – F; *B*

Use the focus term, F, where the focus term, F, is the Zernike Polynomial Term Z(2, 0) as defined in ISO 14999-4:2015, Annex B, Table B.1.

Optional Multi-dimensional term, "$\times\perp n$", term added to the indication for homogeneity or striae:

$2 / A \times\perp n$; $B \times\perp n$ or $02 / A \times\perp n$; $B \times\perp n$ or $12 / A \times\perp n$; $B \times\perp n$

where for basic and optional indications

A is a variable and is to be replaced with the specification for homogeneity in terms of quality class;

B is a variable and is to be replaced with the specification for striae in terms of quality class;

–F is not a variable and indicates that the focus term may be removed from the wavefront map of the homogeneity;

$\times\perp n$ contains the variable *n* and indicates that the specification applies in *n* orthogonal dimensions.

7.3 Homogeneity

7.3.1 Principle of specification

The magnitude of homogeneity is specified as the difference between the maximum and minimum values of the refractive index.

NOTE Annex D offers some guidance for the specification of homogeneity in several common applications.

7.3.2 Quality classes

This document defines six quality classes for homogeneity as given in Table 2.

Table 2 — Six quality classes that may be used for A, the specification for homogeneity (finished parts, finished assemblies, and/or raw material)

Legacy class indicator	New class indicator	Maximum permissible peak-to-valley variation of refractive index 10^{-6}
0	NH100	100
1	NH040	40
2	NH010	10
3	NH004	4
4	NH002	2
5	NH001	1