INTERNATIONAL STANDARD

ISO 8401

Second edition
2017-02

Metallic coatings — Review of methods of measurement of ductility

Revêtements métalliques — Vue d'ensemble sur les méthodes de mesurage de la ductilité

Reference number
ISO 8401:2017(E)

ISO copyright office
Ch. de Blandonnet 8 • CP 401
CH-1214 Vernier, Geneva, Switzerland
Tel. +41 22 749 01 11
Fax +41 22 749 09 47
copyright@iso.org
www.iso.org

Contents

Page

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).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on 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 the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 107, *Metallic and other inorganic coatings*.

This second edition cancels and replaces the first edition (ISO 8401:1986), of which it constitutes a minor revision. The following changes have been made:

— Formula (C.10) has been corrected;

— changes have been made in line with the 2016 edition of the ISO/IEC Directives, Part 2.

Metallic coatings — Review of methods of measurement of ductility

1 Scope

This document specifies general methods for measuring the ductility of metallic coatings of thickness below 200 µm prepared by electroplating, autocatalytic deposition or other processes.

It is applicable to the following methods:

— tests on unsupported foils (separated from the substrate);

— tests of coatings on substrates.

It does not apply to International Standards that include specific methods of testing for individual coatings. In these cases, the methods specified are used in preference to the methods described in this document and are agreed upon beforehand by the supplier and the purchaser.

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:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

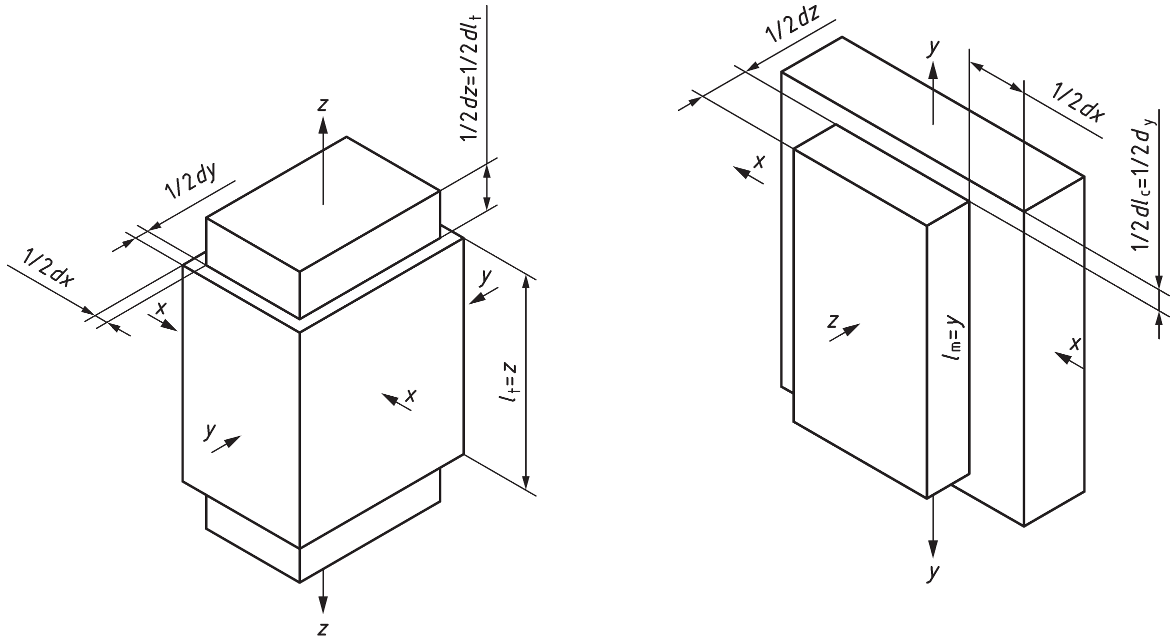
3.1
ductility
ability of a metallic or other coating to undergo plastic or elastic deformation, or both, without fracture or cracking

3.2
linear elongation
ratio of the elongation, Δl, to a definite initial length, l_0, of the test piece

Note 1 to entry: This is taken as a measure of ductility.

Note 2 to entry: Often, this ratio is expressed as a percentage.

Note 3 to entry: Normally, the test pieces are elongated [see Figure 1 a)]. With some bending tests, the outer layer of the test piece, i.e. the plating, is elongated. In bulge tests, however, the surface of the foil is enlarged, requiring calculation of linear elongation from the reduction in the thickness. Using the component of deformation (stretching) in only one axis would give false information about the ductility of the material [see Figure 1 b)]. In those cases, the thinning of the foil, as calculated from the increase in the surface area, is a better measure of the ductility of the material (see Annex B).



$$xyz = (x - dx)(y - dy)(z + dz)$$

$$xyz = xyz + xydz - xzdy - yzdx$$

$$\frac{dz}{z} = \frac{dy}{y} + \frac{dx}{x}$$

$$\frac{dz}{z} > \frac{dy}{y}$$

$$\frac{dl_t}{l_t} = \frac{dz}{z}$$

a) Tensile test **b) Cupping test**

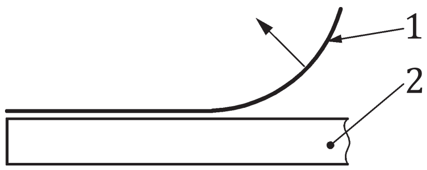
Figure 1 — Tensile and cupping tests

4 Principle

4.1 In the testing of unsupported foils separated from the substrate (see Figure 2), the foils may consist of one or more metallic layers. Therefore, it is possible to measure the ductility of composites and to determine the influence of individual layers on overall ductility. Methods of testing of unsupported foils are described in Clause 5. Methods of producing foils for testing are discussed in Annex A.

4.2 In the testing of coatings on substrates (see Figure 3), it is especially important to determine the exact point of crack initiation of the top layer. Attention is drawn to different methods of discerning this point, by normal or corrected-to-normal vision or with a lens. See the guidance in the individual methods.

These methods can also be used to detect embrittlement of the substrate that may have resulted from the coating process. Methods of testing of coatings on substrates are described in Clause 6.

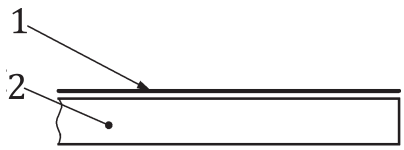


Key

1 metal foil

2 substrate

Figure 2 — Foil, which can be separated from the substrate



Key

1 coating

2 substrate

Figure 3 — Coating on the substrate

4.3 Although ductility is a property of the material and independent of the dimensions of the test piece, thickness of the coating may have an influence on the value of linear elongation ($\Delta l/l_0$).

4.3.1 Very thin layers have different properties as the build-up of the initial layers will be influenced by the properties of the substrate (epitaxy). High internal stresses may be incorporated into the initial layers and these may affect ductility.

4.3.2 It is essential that the test piece has uniform thickness, as thinner spots will give rise to premature cracking. Also, the current density is lower at thinner parts and higher at thicker parts of electroplated test pieces; in this way, current density differences may result in different ductilities. The current density applied should be maintained as uniform as possible over the test piece, and its value reported.

5 Tests on unsupported foils

5.1 General

These techniques involve measurement of a foil which has been separated from the substrate (see Figure 2). In this case, the foil to be tested can also consist of several layers so as to allow measurement of the influence of undercoats on the ductility of the foil sandwich. Examples are gold flash on gold/copper alloys and chromium-plated nickel deposits. Methods of producing unsupported foils are given in Annex A.

Five methods are described: tensile testing (5.2), bending (micrometer bend test) (5.3), folding (vice-bend test) (5.4), hydraulic bulging (5.5) and mechanical bulging (5.6).

5.2 Tensile testing

5.2.1 Principle

Determination of the linear elongation of a foil, which is clamped into the jaws of a tensile testing machine. In this type of stressing, the foil is lengthened, but both the width and the thickness of the foil diminish.

5.2.2 Apparatus

This method may utilize conventional mechanical testing equipment, available commercially and in many metallurgical laboratories[1]. For some applications, tensile testing equipment adapted to microscopic inspection during the test may be used.

5.2.3 Preparation of test pieces

Test pieces may be machined, chipped, punched or cut from the metallic foil or prepared by photoprinting with the help of light-sensitive lacquers or light-sensitive foils which are pressed onto a suitable substrate. After developing the pattern of the test piece, it is plated into the final form. A similar method uses chemical or electrochemical milling of the desired shape from a foil on which has been applied a suitable resist by silk screen printing or by applying a photosensitive resist. These last methods are widely used in the printed circuit industry. The test pieces are usually rectangular in shape (see Table 1 for recommended dimensions), but can be widened at both ends to avoid breaking in the clamping jaws (see Figure 4).

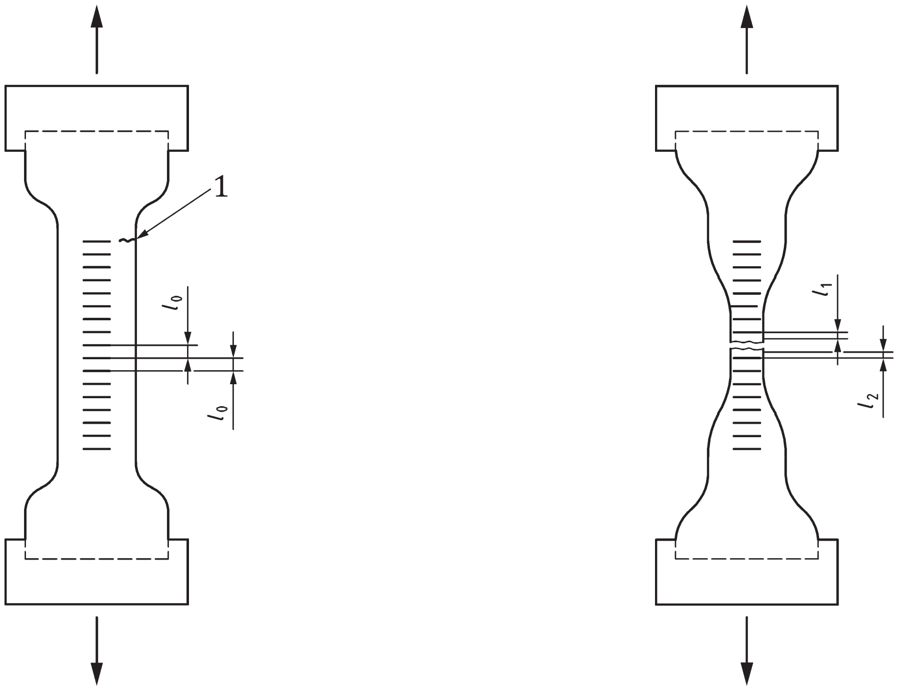
Table 1 — Possible dimensions of tensile test pieces[1]

Gauge length	(mm)	200	50	25
Width	(mm)	40	12,5	6,25

Some methods of preparing the test pieces may cause microcracking at the edges that results in premature failure and erratic results. Test piece preparation involving photoprinting or electroforming is preferred to avoid edge defects.

Test pieces plated into the final form may have thicker edges unless shielding and other techniques are used to ensure uniform current distribution (see Figure 5).

Make equidistant marks on the surface of the test piece as illustrated in Figure 4 a). Determine the distance between the marks before testing.



a) Before testing

b) After testing

$$l_0 + \Delta l = l_1 + l_2$$

$$\frac{\Delta l}{l_0} = \frac{l_1 + l_2 - l_0}{l_0}$$

Key

1 microcracks

Figure 4 — Tensile testing specimen before and after testing

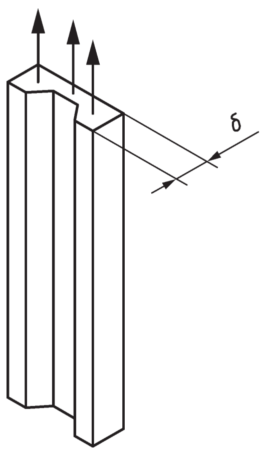


Figure 5 — Plated test pieces with thicker edges

5.2.4 Procedure

Clamp the test piece between the jaws of the tensile test equipment and apply strain using a selected cross-head speed. Determine the distance between the marks on the test pieces after testing [see Figure 4 b)].

5.2.5 Expression of results

5.2.5.1 Calculation

The ductility, D, expressed as a percentage, is given by Formula (1):

$$D = \frac{l_1 + l_2 - l_0}{l_0} \times 100 \tag{1}$$

where

l_0 is the distance between the marks before testing;

$l_1 + l_2$ is the distance between the marks after testing.

5.2.5.2 Coefficient of variation

Mechanically prepared test pieces can have coefficients of variation, $s / \bar{D}$ (where s is the standard deviation and $\bar{D}$ the mean ductility), as high as 20 %.

By plating into the final form using shields to ensure uniform current distribution, test pieces can be produced which have lower coefficients of variation.

5.2.6 Notes on procedure

5.2.6.1 Necking of the test piece [see Figure 4 b)] may require measurement of very small changes in length and the use of a microscope that has a Vernier scale.

5.2.6.2 Mounting fragile thin test pieces into the jaws of a tensile testing machine may give rise to prestressed test pieces which thereby diminish the real value of elongation.

