International Standard 4523

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION•МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ•ORGANISATION INTERNATIONALE DE NORMALISATION

Metallic coatings — Electrodeposited gold and gold alloy coatings for engineering purposes

Revêtements métalliques — Dépôts électrolytiques d'or et d'alliages d'or pour applications industrielles

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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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

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Metallic coatings — Electrodeposited gold and gold alloy coatings for engineering purposes

0 Introduction

This International Standard specifies a range of electrodeposited gold and gold alloy coatings for electrical, electronic and other engineering purposes. Within this International Standard, engineering purposes are defined as those for which the coating has to fulfil primarily non-decorative functional tasks, while decorative purposes are defined as those for which the appearance of the finished article is of prime importance. However, protection against corrosion may be a requirement in both cases.

In this International Standard, no distinction is made between gold and gold alloy coatings, but the coatings shall have a minimum gold content of 58,5 % and, in the case of multi-layer coatings, a minimum gold content of 58,5 % in each layer. Gold coatings complying with the requirements of this International Standard are used for their corrosion and tarnish resistance, solderability, wear resistance, bondability, low and stable electrical contact resistance, and infra-red reflectivity. Attention is drawn to the fact that coatings produced from cyanide-free electrolytes based on complex sulfite ions, and coatings with the hardnesses lower than 90 HKN 25 produced from cyanide electrolytes, show a pronounced tendency to cold weld or gall. The use of such deposits on both surfaces forming mating connections or sliding contacts should therefore be avoided. Gold coatings containing lower than 99,0 % (*m*/*m*) by mass of gold can cause electrical resistance problems in high reliability low electrical impedance and voltage static contacts.

Attention is also drawn to the expression in certain contexts of gold contents in terms of parts per thousand (by mass), also known as "thousandths" (*millièmes*) or "fineness". In this International Standard, percentages by mass to one decimal place are used.

1 Scope and field of application

This International Standard specifies requirements for electrodeposited coatings (single-layer, double-layer or multi-layer) of gold and its alloys for electrical, electronic and other engineering applications on metallic and non-metallic materials.

In the case of double-layer and multi-layer coatings (see 10.1), the thickness requirements apply to the total gold coating, but the requirements for gold content apply to each layer.

It does not apply to coatings on screw threads [see ISO 4042, *Threaded components — Electroplated coatings components* (at present at the stage of draft)] or to coatings on sheet or strip in the unfabricated form.

2 References

ISO 1463, *Metallic and oxide coatings — Measurement of coating thickness — Microscopical method.*

ISO 2064, *Metallic and other non-organic coatings — Definitions and conventions concerning the measurement of thickness.*

ISO 2177, *Metallic coatings — Measurement of coating thickness — Coulometric method by anodic dissolution.*[1)]

ISO 4516, *Metallic and related coatings — Vickers and Knoop microhardness tests.*

ISO 4519, *Electrodeposited metallic coatings and related finishes — Sampling procedures for inspection by attributes.*

ISO 4524, *Metallic coatings — Test methods for electrodeposited gold and gold alloy coatings —*

Part 1 : Determination of coating thickness.

Part 2 : Environmental tests.

Part 3 : Electrographic tests for porosity.

Part 4 : Determination of gold content.

Part 5 : Adhesion tests.

Part 6 : Residual salts test.[2)]

Part 7 : Determination of sheet resistivity.[2)]

IEC Publication 68-2-20, *Basic environmental testing procedures — Test T : Soldering.*

1) At present at the stage of draft. (Revision of ISO 2177-1972.)

2) At present at the stage of draft.

3 Definitions

For the purpose of this International Standard the definitions of ISO 2064, especially that of significant surface which is reproduced in 3.1, together with the additional definitions given in 3.2 to 3.4, apply.

3.1 significant surface : The part of the article covered or to be covered by the coating and for which the coating is essential for serviceability and/or appearance.

3.2 gold or gold alloy coating : An electrodeposited coating of gold or gold alloy having a gold content of not lower than 58,5 % (m/m) (see 10.5).

3.3 double-layer gold or gold alloy coating : A gold or gold alloy coating consisting of two discrete layers of differing gold content, both of which have gold contents not lower than 58,5 % (m/m) (see 10.5).

3.4 multi-layer gold or gold alloy coating : A gold or gold alloy coating consisting of more than two discrete layers of differing gold content, none of which has a gold content lower than 58,5 % (m/m) (see 10.5).

4 Information to be supplied by the purchaser to the electroplater

4.1 Essential information

The following information shall be supplied by the purchaser to the electroplater :

a) the number of this International Standard (ISO 4523);

b) the classification number of the coating required (see clause 6 and 10.3);

c) the significant surface of the article to be electroplated indicated, for example, on drawings or by the provision of suitably marked samples;

d) the surface appearance (see 10.2);

e) the method(s) of adhesion testing to be employed (see 10.6);

f) the sampling procedure to be adopted (see clause 8).

4.2 Additional information

The following additional information may be required and, if so, shall be specified by the purchaser :

a) the minimum gold content of the coating [see 6c)] and details of any intentional alloying elements (see 10.5);

b) the nature of the basis material[1], its surface condition and roughness (see clause 5);

c) any requirements for stress relief before electroplating and/or hydrogen embrittlement relief after electroplating (see clause 7);

d) any special requirements for undercoats (see clause 9);

e) any requirements for the gold contents and thicknesses of the separate layers in double-layer or multi-layer coatings;

f) any requirements for corrosion resistance and/or freedom from porosity and the methods of test to be used (see 10.4);

g) the electrical properties of the coating and the methods of test to be used (see 10.7);

h) the microhardness of the coating and the test method from ISO 4516 to be used (see 10.8);

j) requirements for solderability and the method of test to be used (see 10.9);

k) the wear resistance and the method of test to be used (see 10.10);

m) the ductility of the coating and the method of test to be used (see 10.11);

n) any requirements for freedom from contamination of the finished product (see 10.12);

p) the density of the gold electrodeposit if the thickness test method requires a density correction.

5 Basis material

This International Standard specifies no requirements for the condition, finish or surface roughness of the basis material prior to electroplating. However, it should be recognized that the surface roughness of the coating will be dependent on the initial surface roughness of the basis material and this shall not, therefore, be a cause for rejection of the gold coating.

6 Classification number

The classification number comprises

a) the chemical symbol for the basis metal or for the principal metal, if an alloy, or in the case of non-metallic materials the letters NM followed by an oblique stroke;

b) if appropriate, the chemical symbol(s) for the undercoat metal(s), as shown by the examples given in table 1, followed by an oblique stroke;

c) the chemical symbol for gold, Au, followed if required by a number in parentheses representing the minimum gold content, expressed as a percentage by mass, of the gold coating to one decimal place;

1) If the purchaser supplies the basis material, any lead content shall be notified to the electroplater.

d) a number indicating the minimum thickness, in micrometres, of the gold coating on the significant surface.

Table 1 — Symbols

Symbol	Significance
Ni	Nickel
Cu	Copper
Cu/Ni	Nickel on copper
Sn-Ni	Tin-nickel alloy

Examples of complete classification numbers are

— a gold coating, having a thickness of 5 µm (minimum), on steel, using a nickel undercoat, has the classification number Fe/Ni/Au 5

— a 98,0 % gold coating, having a thickness of 2 µm (minimum), on zinc alloy, using an undercoat of nickel on copper, has the classification number Zn/Cu/Ni/Au(98,0)2

— a 99,5 % gold coating, having a thickness of 0,5 µm (minimum), on copper alloy, has the classification number Cu/Au(99,5)0,5.

7 Heat treatment of steels

7.1 General

Heat treatment as specified in 7.3 and 7.4 shall be performed on certain basis metals to reduce the risk of damage by hydrogen embrittlement. In all cases, the duration of heat treatment shall commence from the time at which the whole of each part attains the specified temperature.

Parts made from steels with maximum specified tensile strengths greater than 1 050 MPa[1] (corresponding hardness values approximately 34 HRC, 340 HV or 325 HB) and surface-hardened parts will require heat treatment. Preparation involving cathodic treatments in alkaline or acid solutions shall be avoided. Additionally, the selection of electroplating solutions with high cathodic efficiencies is recommended for steel components with tensile strengths greater than 1 450 MPa (corresponding hardness values approximately 45 HRC, 440 HV or 415 HB).

7.2 Categorization of steels

7.2.1 With the exception of surface-hardened parts (see 7.3.2 and 7.4.2), the heat-treatment conditions shall be selected on the basis of the specified maximum tensile strength. Steels shall be categorized according to specified maximum tensile strength according to table 2. If the steel specification is only in terms of minimum tensile strength, the corresponding maximum tensile strength shall be determined from table 2.

Table 2 — Categories of steels and maximum tensile strengths corresponding to specified minimum tensile strengths

Minimum specified tensile strength, $R_{m\,min}$ (MPa)	Corresponding maximum tensile strength, $R_{m\,max}$ (MPa)
$R_{m\,min} \leqslant 1\,000$	$R_{m\,max} \leqslant 1\,050$
$1\,000 < R_{m\,min} \leqslant 1\,400$	$1\,050 < R_{m\,max} \leqslant 1\,450$
$1\,400 < R_{m\,min} \leqslant 1\,750$	$1\,450 < R_{m\,max} \leqslant 1\,800$
$1\,750 < R_{m\,min}$	$1\,800 < R_{m\,max}$

7.2.2 If neither the maximum nor the minimum tensile strength is specified for the steel, Vickers hardness values of 340, 440 and 560 HV shall be regarded as equivalent to maximum tensile strengths of 1 050, 1 450 and 1 800 MPa, respectively, and these strengths shall be used to select the heat treatment conditions.

7.3 Stress relief before electroplating

7.3.1 The conditions given in table 3 are recommended if the purchaser requires the parts to be stress relieved before electroplating, although different conditions, namely suitable combinations of shorter periods at appropriate higher temperatures, may be used if they have been shown to be effective. The heat treatment shall be carried out before the commencement of any preparation or cleaning treatment using aqueous solutions.

Table 3 — Heat-treatment conditions for stress relief before electroplating (excluding surface-hardened parts)

Maximum specified tensile strength, $R_{m\,max}$	Temperature	Time
MPa	°C	h
$R_{m\,max} \leqslant 1\,050$	None required	—
$1\,050 < R_{m\,max} \leqslant 1\,450$	190 to 220	1
$1\,450 < R_{m\,max} \leqslant 1\,800$	190 to 220	18
$1\,800 < R_{m\,max}$	190 to 220	24

7.3.2 Surface-hardened parts shall be heat treated at 130 to 150 °C for not less than 5 h, or for shorter periods at higher temperatures if the resulting loss of surface hardness of the substrate is acceptable.

7.3.3 If stress relief is given after shot peening or other cold working processes, the temperature shall not exceed 220 °C.

7.4 Hydrogen embrittlement relief after electroplating

7.4.1 The treatment shall be carried out as soon as possible, and in any case not later than 4 h after electroplating, according to the conditions specified in table 4.

1) 1 MPa = 1 N/mm^2

Table 4 — Heat-treatment conditions for hydrogen embrittlement relief after electroplating (excluding surface-hardened parts)

Maximum specified tensile strength, $R_{m\,max}$	Temperature	Time
MPa	°C	h
$R_{m\,max} \leqslant 1\,050$	None required	—
$1\,050 < R_{m\,max} \leqslant 1\,450$	190 to 220	8
$1\,450 < R_{m\,max} \leqslant 1\,800$	190 to 220	18
$1\,800 < R_{m\,max}$	190 to 220	24

7.4.2 Surface-hardened parts shall be heat treated at a temperature between 190 and 220 °C for not less than 2 h.

7.4.3 Other temperatures and durations may be specified and used if they have been shown to be effective for the particular part, and are acceptable to the purchaser. However, parts shall not be heat treated above their tempering temperature.

NOTE — Attention is drawn to the fact that the heat treatments specified can cause interdiffusion of the gold coating and the substrate. Undercoats of nickel reduce this effect.

8 Sampling

A random sample of the size required by ISO 4519 shall be selected from the inspection lot. The articles in the sample shall be inspected for conformance to the requirements of this International Standard and the lot shall be classified as conforming or not conforming to each requirement according to the criteria of the sampling plans in ISO 4519.

9 Requirements for undercoats

Undercoats may be necessary on any basis material for the following reasons :

a) to improve corrosion resistance;

b) to improve adhesion;

c) to prevent diffusion;

d) to prevent contamination of the electrolyte;

e) to improve solderability and its retention;

f) to reduce surface roughness;

g) to reduce porosity.

Typical undercoats used are copper, nickel, palladium, tin-nickel alloy and combinations of these metals (see the note).

The thickness requirements for undercoats given in table 5 are minimum values. For arduous conditions of service, greater thicknesses may be required and shall be specified by the purchaser. Other undercoats to be used for special purposes shall also be specified by the purchaser.

NOTE — To promote good adhesion it may be necessary to deposit a gold strike coating immediately prior to the main gold deposition.

Table 5 — Requirements for undercoats

Basis material	Undercoat(s)	Minimum thickness of undercoat(s) (μm)
Copper	None	—
Copper alloys, notably free-cutting brass containing lead	Ni (nickel)1), Cu (copper) or Sn-Ni (tin-nickel alloy)	1,25
Ferrous materials (other than austenitic stainless steel)	Ni (nickel)1)	10
	Cu/Ni (copper + nickel)1)	10 (Cu) + 5 (Ni)
Austenitic stainless steel2)	Either an acid nickel strike [Wood's bath 3)] or an acid gold strike will normally be required	Thin coating, to promote adhesion of the gold coating
Zinc and zinc alloys	Cu/Ni (copper + nickel)1)	8 (Cu) + 10 (Ni)
Aluminium and aluminium alloys	Ni (nickel)1) 4)	20
Other basis materials and basis metals with soldered joints	Nickel1) or copper may be required to meet functional or other requirements of this International Standard	To be agreed

1) Low stress nickel undercoats should normally be used.

2) If a gold-electroplated austenitic stainless steel is intended for use in a chloride environment, a substantial nickel undercoat will be necessary and its thickness shall be specified.

3) A Wood's bath consists of a solution of 240 g of nickel chloride hexahydrate ($NiCl_2 \cdot 6H_2O$) and 85 ml of 36 % (m/m) hydrochloric acid per litre. The parts are made anodic for not more than 2 min and then cathodic for 6 min, using depolarized nickel electrodes, without anode bags, at room temperature and a current density of 300 A/m^2. If current reversal is not feasible, the anodic treatment can be replaced by immersion in the solution, without current flow, for 15 min.

4) An initial copper coating may be employed under the nickel coating but the thickness of the nickel coating should not be reduced.

If required, the thickness of any undercoat shall be determined by the microscopical method specified in ISO 1463 or the coulometric method specified in ISO 2177.

10 Requirements for gold and gold alloy coatings

10.1 General

Gold and gold alloy coatings shall normally consist of a single layer but double-layer or multi-layer coatings may be specified [see 4.2 e)]. The individual layers shall not, however, be separated by any of the test methods specified in this International Standard.

10.2 Appearance

The electroplated article shall be free from extraneous soil and from damage. In the case of selectively electroplated articles, the amount of stain occurring at the boundary between the areas of the article which are gold electroplated and those which are not gold electroplated shall be the subject of agreement between the parties concerned.

Over the significant surface, the electroplated article shall be free from electroplating defects such as pits, roughness, cracks, or uncoated areas visible when viewed at a magnification of X 8 (see the note). In addition, blistering or other signs of poor adhesion cannot be tolerated on any surface of the article.

On articles where a contact mark on the significant surface is unavoidable, its position shall be the subject of agreement between the supplier and the purchaser.

If required, a preliminary sample with the required finish shall be supplied or approved by the purchaser.

NOTE — If using illuminated viewers, a X 4 magnification is acceptable.

10.3 Thickness

Gold coatings are classified by thickness and the preferred range for general engineering applications is given in table 6. Any other coating thickness may be called up by specifying the required minimum local thickness at the appropriate place in the classification number.

The thickness of the coatings shall be measured over a reference area (see ISO 2064) by an appropriate method selected by the purchaser from those specified in ISO 4524/1 on any part of the significant surface.

Table 6 — Typical thicknesses of gold and gold alloy coatings

Minimum thickness
µm
0,25
0,5
1
2,5
5
10

Microscopical, profilometric and interferometric methods measure coating thickness, d, directly, whereas beta back-scatter, gravimetric, chemical analysis, X-ray spectrometric and coulometric methods fundamentally measure mass per unit area (surface density), ϱ_A, and therefore require a correction for density. In those methods requiring a value for density of the electrodeposited coating, the true density, ϱ, of the gold alloy shall be used and shall be specified by the purchaser in accordance with 4.2 p).

If, however, the true density is not known, or if no value has been provided by the purchaser, for pure gold deposits, a density of 19,3 g/cm^3 shall be used. For gold alloy deposits, a suitable arithmetically calculated value based upon the actual alloy composition shall be used.

The use of these calculated or assumed values may result in a thickness lower than the true thickness. The relationship between these three quantities is given by the equation

$$d = \frac{\varrho_A}{\varrho}$$

where

d is the coating thickness, in centimetres;

ϱ_A is the mass per unit area, in grams per square centimetre, of the coating;

ϱ is the density, in grams per cubic centimetre, of the coating.

10.4 Porosity and corrosion resistance

Where corrosion resistance and/or freedom from porosity are important and if specified by the purchaser, the parts shall be subjected to one or more of the environmental or porosity tests specified in ISO 4524/2 and ISO 4524/3.

All the tests given in ISO 4524/2 and ISO 4524/3 can be used for flat surfaces. The gas exposure tests given in ISO 4524/2 and the electrographic gelatine test given in ISO 4524/3 can be used for curved surfaces.

Acceptance numbers shall be specified by the purchaser.

10.5 Composition

The minimum gold content of the coating, whether single-layer, double-layer or multi-layer, shall if required be specified by the purchaser and included at the appropriate place in the classification number. In no case shall this be lower than 58,5 % (m/m).

Where alloy compositions are concerned, the gold and metal alloy contents shall be specified; no account need be taken of non-metallic inclusions except for electronic or electrical applications. However, the physical properties of the coating may be affected by the presence of such inclusions. If specified by the purchaser, the gold content shall be determined by an appropriate method selected by the purchaser from those specified in ISO 4524/4.

10.6 Adhesion

Coatings shall be capable of passing one or more of the adhesion tests given in 10.6.1 to 10.6.4, as specified by the purchaser.

NOTE — The preparation of cross-sections for metallographic thickness measurement often provides an indication of poor adhesion. The action of grinding and polishing creates a shear force which may cause the separation of the coating from the substrate, and this separation can be observed in the measuring microscope.

10.6.1 Burnishing test

When the specimen is tested by the burnishing test specified in ISO 4524/5, there shall be no sign of blistering of the coating.

10.6.2 Adhesive tape test

When the specimen is tested by the adhesive tape test specified in ISO 4524/5, no part of the coating shall be removed by the adhesive tape.

10.6.3 Thermal shock test

When the specimen is tested by the thermal shock test specified in ISO 4524/5, there shall be no sign of blistering or detachment of the coating.

10.6.4 Bend test

When the specimen is tested by the bend test specified in ISO 4524/5, it shall withstand three bends without detachment of the coating.

Failure of the substrate due to microcracking or macrocracking shall not be cause for rejection provided that the coating has not exfoliated.

10.7 Electrical properties

If the electrical properties of the coating are important, these shall be specified by the purchaser together with the method or methods of assessing such properties. A suitable method for the determination of sheet resistivity is specified in ISO 4524/7.

10.8 Hardness

If a value for hardness is specified the hardness of the coating shall be determined by one of the methods specified in ISO 4516.

10.9 Solderability

If specified, gold coatings shall be subjected to a solderability test. The form of test and any artificial ageing treatment carried out before the test shall be appropriate to the intended service of the electroplated product and details shall be agreed between the parties. A test is described in IEC Publication 68-2-20.

Attention is also drawn to the need to guard against formation of brittle joints and against possible decline in solderability of thin, porous gold coatings under storage. Soft soldered joints on gold coatings may contain intermetallic compounds which are hard and brittle. If too much compound is formed, the joint has an inadequate resistance to shear, fatigue or impact. The risk of developing brittleness becomes larger with increases in soldering temperature or in gold thickness, and may be greater in the case of some alloyed gold coatings. If the coating thickness exceeds 1,5 µm, special techniques should be employed. When thin coatings are used, some loss of solderability may occur during storage; this may be avoided by choosing a suitable undercoat.

10.10 Wear resistance

If the wear resistance of the coating is important, it shall be specified by the purchaser together with its method of measurement.

10.11 Ductility

If the ductility of the coating is important, it shall be specified by the purchaser together with its method of measurement.

10.12 Freedom from contamination

The gold or gold alloy coated parts shall be thoroughly rinsed and dried after electroplating. If specified by the purchaser, the parts shall be subjected to the residual salts test specified in ISO 4524/6.

An increase in conductivity of not more than 150 µS/m shall be considered acceptable.