



Standard Specification for Electrodeposited Coatings of Gold for Engineering Uses¹

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This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 *Purity*—This specification covers requirements for electrodeposited gold coatings that contain not less than 99.00 mass % gold and that are used for engineering applications.

1.2 Specifically excluded from this specification are autocatalytic, immersion, and vapor deposited gold coatings.

1.3 *Properties*—Gold coatings conforming to this specification are employed for their corrosion and tarnish resistance (including resistance to fretting corrosion and catalytic polymerization), bondability, low and stable contact resistance, solderability, and infrared reflectivity. Several types of coatings, differing in gold purity and hardness, are covered by this specification.

1.4 The values stated in SI units are to be regarded as the standard. Values provided in parentheses are for information only.

1.5 The following hazards caveat pertains only to the test methods section, Section 9, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:

- B 32 Specification for Solder Metal²
- B 183 Practice for Preparation of Low-Carbon Steel for Electroplating³
- B 242 Practice for Preparation of High-Carbon Steel for Electroplating³
- B 253 Guide for Preparation of Aluminum Alloys for Electroplating³
- B 254 Practice for Preparation of and Electroplating on Stainless Steel³
- B 281 Practice for Preparation of Copper and Copper Base Alloys for Electroplating and Conversion Coatings³

¹ This specification is under the jurisdiction of ASTM Committee B-8 on Metallic and Inorganic Coatings and is the direct responsibility of Subcommittee B08.08 on Engineering Coatings.

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² *Annual Book of ASTM Standards*, Vol 02.04.

³ *Annual Book of ASTM Standards*, Vol 02.05.

- B 322 Practice for Cleaning Metals Prior to Electroplating³
- B 343 Practice for Preparation of Nickel for Electroplating with Nickel³
- B 374 Terminology Relating to Electroplating³
- B 481 Practice for Preparation of Titanium and Titanium Alloys for Electroplating³
- B 482 Practice for Preparation of Tungsten and Tungsten Alloys for Electroplating³
- B 487 Test Method for Measurement of Metal and Oxide Coating Thicknesses by Microscopical Examination of a Cross Section³
- B 489 Practice for Bend Test for Ductility of Electrodeposited and Autocatalytically Deposited Metal Coatings on Metals³
- B 499 Test Method for Measurement of Coating Thicknesses by the Magnetic Method: Nonmagnetic Coatings on Magnetic Basis Metals³
- B 504 Test Method for Measurement of Thickness of Metallic Coatings by the Coulometric Method³
- B 507 Practice for Design of Articles to Be Electroplated on Racks³
- B 542 Terminology Relating to Electrical Contacts and Their Use⁴
- B 558 Practice for Preparation of Nickel Alloys for Electroplating³
- B 567 Test Method for Measurement of Coating Thickness by the Beta Backscatter Method³
- B 568 Test Method for Measurement of Coating Thickness by X-Ray Spectrometry³
- B 571 Test Methods for Adhesion of Metallic Coatings³
- B 578 Test Method for Microhardness of Electroplated Coatings³
- B 602 Test Method for Attribute Sampling of Metallic and Inorganic Coatings³
- B 697 Guide for Selection of Sampling Plans for Inspection of Electrodeposited Metallic and Inorganic Coatings³
- B 735 Test Method for Porosity in Gold Coatings on Metal Substrates by Nitric Acid Vapor³
- B 741 Test Methods for Porosity in Gold Coatings on Metal Substrates by Paper Electrography³
- B 748 Test Method for Measurement of Thickness of Metallic Coatings by Measurement of Cross Section with a

⁴ *Annual Book of ASTM Standards*, Vol 03.04.

- Scanning Electron Microscope (SEM)³
- B 762 Method of Variables Sampling of Metallic and Inorganic Coatings³
- B 765 Guide for Selection of Porosity Tests for Electrodeposits and Related Metallic Coatings³
- B 799 Test Method for Porosity in Gold and Palladium Coatings by Sulfurous Acid/Sulfur-Dioxide Vapor⁴
- B 809 Test Method for Porosity in Metallic Coatings by Humid Sulfur Vapor (Flowers-of-Sulfur)³
- D 509 Test Methods of Sampling and Grading Rosin⁵
- D 1125 Test Methods for Electrical Conductivity and Resistivity of Water⁶
- D 3951 Practice for Commercial Packaging⁷
- F 390 Test Method for Sheet Resistance of Thin Metallic Films with a Collinear Four-Probe Array⁸
- 2.2 U.S. Government Standards:
- MIL STD 105 Sampling Procedures and Tables for Inspection by Attributes⁹
- MIL-G-45204 Gold Plating, Electrodeposited⁹

3. Terminology

- 3.1 *Definitions*—For definitions of terms used in this specification refer to Terminologies B 374 or B 542.
- 3.2 *Definitions of Terms Specific to This Standard:*
- 3.2.1 *significant surfaces*—defined as those normally visible (directly or by reflection) or essential to the serviceability or function of the article. Can be the source of corrosion products or tarnish films that interfere with the function or desirable appearance of the article. The significant surfaces shall be indicated on the drawings of the parts or by the provision of suitably marked samples.
- 3.2.2 *underplating*—a metallic coating layer between the basis metal or substrate and the topmost metallic coating. The thickness of an underplating is usually greater than 1 µm (40 µin.), in contrast to a strike or flash, which is thinner.

4. Classification

- 4.1 *Types of Coatings*—A coating shall be specified by a combination of the following:
 - 4.1.1 type, characterizing minimum purity in accordance with 4.2.1,
 - 4.1.2 code, designating Knoop hardness in accordance with 4.2.2, and
 - 4.1.3 a numeral designating thickness in micrometres in accordance with 4.3.
- 4.2 *Purity and Hardness:*
- 4.2.1 *Purity*—Purity shall be specified by ASTM type. The military standard designation of type is included for reference.

Mass Percent Gold, Minimum	ASTM Type	MIL-G-45204
99.90	1	III
99.70	2	I
99.00	3	II

⁵ Annual Book of ASTM Standards, Vol 06.03.
⁶ Annual Book of ASTM Standards, Vol 11.01.
⁷ Annual Book of ASTM Standards, Vol 15.09.
⁸ Annual Book of ASTM Standards, Vol 10.04.
⁹ Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

4.2.2 *Hardness*—Hardness values shall be indicated by ASTM code. The military standard designation of grade is included for reference.

Knoop Hardness Range	ASTM Code	MIL-G-45204
90 HK ₂₅ maximum	A	A
91–129 HK ₂₅	...	B
90–200 HK ₂₅	B (see Note 1)	...
130–200 HK ₂₅	C	C
>200 HK ₂₅	D	D

NOTE 1—This designation is retained, although rarely used, because some specifications reference it.

4.2.3 *Relationship Between Purity and Hardness*—The following combinations of purity and hardness ranges are representative of good commercial practice:

Type	Code
1	A only
2	A, B, and C
3	C and D

4.3 *Thickness*—Thickness shall be specified by an arabic numeral that designates the minimum linear thickness in micrometres. Examples of commonly specified thicknesses are shown in Table 1. Unless otherwise specified, the density of gold is assumed to be 19.3 g/cm³ for Type 1 and 17.5 g/cm³ for Type 2 and Type 3.

- 4.3.1 See 7.4.2 for thickness tolerances.
- 4.3.2 Instead of specifying the thickness in micrometres, the purchaser may specify the mass of gold per unit area (coating weight) in milligrams per square centimeter. Unless otherwise specified, the density of gold is assumed to be 19.3 g/cm³ for Type 1 and 17.5 g/cm³ for Type 2 and Type 3.

NOTE 2—When significant surfaces are involved on which the specified thickness of deposit cannot readily be controlled, such as threads, holes, deep recesses, bases of angles, and similar areas, the purchaser and the manufacturer should recognize the necessity for either thicker deposits on the more accessible surfaces or for special racking. Special racks may involve the use of conforming, auxiliary, bipolar electrodes, or nonconducting shields.

5. Ordering Information

- 5.1 To make the application of this standard complete, the purchaser needs to supply the following information to the seller in the purchase order or other governing document.
 - 5.1.1 The name, designation, and date of issue of this specification.
 - 5.1.2 Classification: type, code, and thickness (or mass per unit area) (see Section 4).
 - 5.1.3 Presence and thickness of underplating, if required (see 3.2.1).
 - 5.1.4 Significant surfaces shall be specified (see 3.2.2).
 - 5.1.5 Requirement, if any, for performance testing such as porosity testing (see 9.6), solderability testing (see Appendix X4), ductility testing (see 9.7), etc.

TABLE 1 Coating Thickness

Class	Minimum Thickness, µm
0.25	0.25
0.50	0.50
0.75	0.75
1.0	1.0
1.25	1.25
2.5	2.5
5.0	5.0

5.1.6 If the substrate is one that requires a nickel underplating (see 6.6.1 and Appendix X6).

5.1.7 Whether or not stress relief has been or is to be done (steel parts only).

5.1.8 Sampling plan employed (see Section 8).

6. Manufacture

6.1 Any process that provides an electrodeposit capable of meeting the specified requirements is acceptable.

6.2 Substrate:

6.2.1 The surface condition of the basis metal should be specified and should meet this specification prior to the plating of the parts.

6.2.2 Defects in the surface of the basis metal such as scratches, porosity, pits, inclusions, roll and die marks, laps, cracks, burrs, cold shuts, and roughness may adversely affect the appearance and performance of the deposit, despite the observance of the best plating practice. Any such defects on significant surfaces shall be brought to the attention of the purchaser.

6.2.3 The basis metal shall be subject to such cleaning procedures as are necessary to ensure a satisfactory surface for subsequent electroplating (see Practices B 183, B 242, Guide B 253, Practices B 254, B 281, B 322, B 343, B 481, B 482, and B 558).

6.2.4 Proper preparatory procedures and thorough cleaning of the basis metal are essential for satisfactory adhesion and performance of these coatings. The surface must be chemically clean and continuously conductive, that is, without inclusions or other contaminants. They must be smooth and as free of scratches, gouges, nicks, and similar imperfections as possible.

NOTE 3—A metal finisher can often remove defects through special treatments such as grinding, polishing, abrasive blasting, chemical treatments, and electropolishing. However, these may not be normal in the treatment steps preceding the plating and a special agreement is indicated.

6.3 If required (see 5.1.7), steel parts with a hardness greater than 31 HRC shall be given a suitable stress relief heat treatment prior to plating. Such stress relief shall not reduce the hardness to a value below the specified minimum. Acid pickling of high strength steels shall be avoided.

6.3.1 The coating shall be applied after all basis metal heat treatments and mechanical operations on significant surfaces have been completed.

6.4 *Racking*—Parts should be positioned so as to allow free circulation of solution over all surfaces. The location of rack or wire marks in the coating shall be agreed upon between the producer and the supplier.

6.5 Plating Process:

6.5.1 *Nickel Underplating*—For thickness classes less than 5.0, a nickel underplating shall be applied before the gold coating when the product is made from copper or copper alloy. Nickel underplatings are also applied for other reasons (see Appendix X6).

NOTE 4—When the thickness of the nickel underplate has a detrimental impact on the mechanical properties or bondability of the substrate, the nickel thickness may be reduced to a non-detrimental level as specified by the purchaser.

NOTE 5—In certain instances in which high-frequency analog signals

are employed, such as in wave guides, the magnetic properties of nickel may attenuate the signal.

NOTE 6—In applications in which forming or flaring operations are to be applied to the plated component, a ductile nickel electrodeposit should be specified.

6.5.2 *Strikes*—It is recommended to apply a gold strike to the underplate or substrate, except if the latter is silver or platinum, prior to applying the gold top coating.

6.5.3 *Plating*—Good practice calls for parts to be electrically connected when entering the gold plating solution. A minimum of 0.5 V is suggested.

NOTE 7—For rack and barrel plating processing, residual plating salts can be removed from the articles by a clean, hot (50 to 100°C) water rinse. A minimum rinse time of 2.5 min (rack) or 5 min (barrel) is suggested. Best practice calls for a minimum of three dragout rinses and one running rinse with dwell times of 40 s in each station when rack plating and 80 s when barrel plating. Modern, high-velocity impingement-type rinses can reduce this time to a few seconds. This is particularly useful in automatic reel-to-reel applications in which dwell times are significantly reduced.

7. Coating Requirements

7.1 *Nature of Coating*—The gold deposit shall meet the appropriate purity requirements as put forth in the following:

7.1.1 Type 1 (Type III according to MIL-G-45204) coatings shall contain at least 99.90 mass % gold. Individual metallic impurities shall not be present in a quantity greater than 0.04 mass %. Iron, nickel, and cobalt combined shall be less than 0.05 mass %, and none of these three elements shall be present in an amount greater than 0.03 mass %. The gold content shall be calculated by difference.

7.1.2 Type 2 (Type 1 according to MIL-G-45204) coatings shall contain at least 99.70 mass % gold. For Type 2 Code A coatings only, metallic hardening agents such as nickel, cobalt, and iron combined shall be less than 0.05 mass % and, none of these three elements shall be present in an amount greater than 0.03 mass %. The gold content shall be calculated by difference.

7.1.3 Type 3 (Type II according to MIL-G-45204) coatings shall contain at least 99.00 mass % gold and may contain metallic hardening agents, which may be present in amounts greater than 0.1 mass %. All other metals shall be considered impurities and shall not be present in amounts greater than 0.1 mass % each. The gold content shall be calculated by difference.

7.2 *Hardness*—The gold coating shall have a Knoop hardness within the specified range as shown in 4.2.2 when tested in accordance with 9.2.

7.3 *Appearance*—Gold coatings shall be coherent, continuous, and have a uniform appearance to the extent that the nature of the basis metal and good commercial practices permit.

7.4 Thickness:

7.4.1 The gold coating shall have a thickness on the significant surfaces in accordance with 4.3 unless otherwise specified.

NOTE 8—Where Type 2 (Code B or C) or Type 3 (Code B or C) gold is specified, improved protection of the underlying metals can be obtained by applying a duplex gold composite coating consisting of an underlying layer of Type 1 (Code A) gold. Typical thicknesses of the Type 1 gold underlayer are 10 to 30 % of the total specified thickness. However, care

must be taken to ensure that the thickness of the Type 2 or Type 3 gold topcoat is sufficient so as not to compromise wear properties. When measuring the total gold thickness of duplex composite coatings, a density of 17.5 g/cm³ should be employed (see 9.4).

7.4.2 The thickness of the gold coating shall be equal to or exceed the specified thickness throughout the significant surface (see 3.2.2). When plated parts are used in mating applications, the maximum thickness shall not exceed the tolerance specified for the part on its engineering drawing. It is customary that allowance for plated coatings be included within the part tolerance.

NOTE 9—The coating thickness requirement of this specification is a minimum requirement: that is, the coating thickness is required to equal or exceed the specified thickness throughout the significant surfaces, while conforming to all maximum allowed thicknesses created by part dimensional tolerances given in the engineering drawing. Variation in the coating thickness from point to point on a coated article is an inherent characteristic of electroplating processes. Therefore, the coating thickness at any single point on the significant surface will sometimes have to exceed the specified value in order to ensure that the thickness equals or exceeds the specified value at all points. Hence, most average coating thicknesses will be greater than the specified value; how much greater is largely determined by the shape of the article (see Practice B 507) and the characteristics of the plating process. In addition, the average coating thickness on articles will vary from article to article within a production lot. Therefore, if all the articles in a production lot are to meet the thickness requirement, the average coating thickness for the production lot as a whole will be greater than the average necessary to ensure that any single article meets the requirement (see 8.1).

7.5 *Adhesion*—The gold coatings shall be adherent to the substrate when tested by one of the procedures summarized in 9.5.

7.6 *Integrity of the Coating:*

7.6.1 *Gross Defects/Mechanical Damage*—The coatings shall be free of visible mechanical damage and similar gross defects when viewed at magnifications up to 10×. For some applications this requirement may be relaxed to allow for a small number of such defects (per unit area), especially if they are outside or on the periphery of the significant surfaces (see 7.6.2).

7.6.2 *Porosity*—Almost all as-plated electrodeposits contain some porosity. The tolerable amount of porosity in the coating depends on the severity of the environment that the article is likely to encounter during service or storage. If the pores are few in number or away from the significant surfaces, their presence can often be tolerated. Such acceptance (or pass-fail) criteria, if required, shall be part of the product specification for the particular article or coating requiring the porosity test (see 9.6 for porosity testing).

8. Sampling

8.1 The producer is urged to employ statistical process control in the coating process. Properly performed, this process will ensure coated products of satisfactory quality and will reduce the amount of acceptance inspection. The sampling plan used for the inspection of the quality of the coated articles shall be as agreed upon between the purchaser and the supplier.

NOTE 10—Usually, with a collection of coated articles, the inspection lot (see 8.2) is examined for compliance with the requirements placed on the articles, a relatively small number of the articles, the sample, is selected at random and is inspected. The inspection lot is then classified as

complying with the requirements based on the results of the inspection of the sample. The size of the sample and the criteria of compliance are determined by the application of statistics. The procedure is known as sampling inspection. Test Method B 602, Guide B 697, and Method B 762 contain sampling plans that are designed for the sampling inspection of coatings. Test Method B 602 contains four sampling plans, three for use with tests that are nondestructive and one with those that are destructive. The buyer and seller may agree on the plan or plans to be used. If they do not, Test Method B 602 identifies the plan to be used. Guide B 697 provides a large number of plans and also gives guidance in the selection of a plan. When Guide B 697 is specified, the buyer and seller need to agree on the plan to be used. Method B 762 can be used only for coating requirements that have a numerical limit, such as coating thickness. The test must yield a numerical value and certain statistical requirements must be met. Method B 762 contains several plans and also gives instructions for calculating plans to meet special needs. The buyer and the seller may agree on the plan or plans to be used. If they do not, Method B 762 identifies the plan to be used.

8.2 An inspection lot shall be defined as a collection of coated articles that are of the same kind; that have been produced to the same specifications; that have been coated by a single supplier at one time, or at approximately the same time; under essentially identical conditions; and that are submitted for acceptance or rejection as a group.

9. Test Methods

9.1 *Deposit Purity*—Use any recognized method to determine quantitatively the metallic impurities present. Atomic absorption spectrophotometry (or any methods with demonstrated uncertainty less than 10 %) may be used to determine the metallic impurities. Initial scanning should be carried out for all elements in order to detect any unknown or unexpected metallic impurities. Determine deposit purity by subtracting total impurities from 100 %.

9.2 *Hardness*—Measure hardness in accordance with Test Method B 578.

9.3 *Appearance*—The coating shall be examined at magnifications up to 10× for conformance to the requirements of appearance.

9.4 *Thickness and Mass per Unit Area*—Measure thickness by methods outlined in Test Methods B 487, B 567, B 568, or B 748. The method chosen shall be such as to give an uncertainty of less than 10 % on the particular coating being measured.

9.4.1 *Thickness*—The beta backscatter, X-ray fluorescence spectrometry, and coulometric methods measure the mass of gold per unit area that is present over the measured area. The cross-sectioning and magnetic methods measure the geometrical thickness of the gold present. Since many gold coatings have a density lower than the theoretical density of gold (19.3 g/cm³), instruments utilizing the measuring principles in Test Methods B 504, B 567, and B 568 will often give lower readings than the microscopical cross-section method. To convert mass of gold per unit area that is present over the measured area to a geometrical thickness, it is necessary to use standards having a density identical to that of the coatings to be measured, or to multiply the reading obtained by factor, *f*.

$$f = \frac{19.3}{d} \quad (1)$$