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Standard Specification for Electrodeposited Coatings of Palladium- Cobalt Alloy for Engineering Use[1]

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1. Scope

1.1 This specification covers requirements for electrodeposited palladium-cobalt alloy coatings containing approximately 80% of palladium and 20% of cobalt. Composite coatings consisting of palladium-cobalt with a thin gold overplate for applications involving electrical contacts are also covered. Palladium and palladium-cobalt remain competitive finishes for high reliability applications.

1.2 *Properties*—Palladium is the lightest and least noble of the platinum group metals (1)[2]. IIt has the density of 12 gm per cubic centimeter, specific gravity of 12.0, that is substantially lower than the density of gold, 19.29 gm per cubic centimeter, specific gravity 19.3, and platinum 21.48 gm per cubic centimeter, specific gravity 21.5. The density of cobalt on the other hand is even less than palladium. It is only 8.69 gm per cubic centimeter, specific gravity 8.7. This yields a greater volume or thickness of coating and, consequently, some saving of metal weight and reduced cost. Palladium-cobalt coated surface provides a hard surface finish (ASTM E18) thus decreasing wear and increasing durability. Palladium-cobalt coated surface also has very low coefficient of friction 0.43 compared to hard gold 0.60 thus providing lower mating and unmating forces for electrical contacts (1) [2]. Palladium-cobalt has smaller grain size (ASTM E112), 50 – 150 Angstroms, compared to Hard Gold 200 – 250 Angstroms (1)[2]. 5 – 15 nanometer, compared to hard gold 20 – 25 nanometer (1)[2]. Palladium-cobalt has low porosity (ASTM B799) 0.2 porosity index compared to hard gold 3.7 porosity index (1)[2]. Palladium-cobalt coated surface has higher ductility (ASTM B489) 3-7 than that of hard gold <3 (1)2. The palladium-cobalt coated surface is also thermally more stable 395°C than hard gold 150°C, and silver 170°C. The following Table 1 compares the hardness range of electrodeposited palladium-cobalt with other electrodeposited noble metals and alloys (3,4).[2]

TABLE 1 - Hardness of Noble Metals

	Approximate Hardness (HK_{25})
Gold	50–250
Palladium	75–600
Platinum	150–550
Palladium-Nickel	300–650
Palladium-Cobalt	500–650
Rhodium	750–1100
Ruthenium	600–1300

1.3 *Units*—The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.4 *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. Some specific hazards statements are given in Section 7 on Hazards.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

B183 Practice for Preparation of Low-Carbon Steel for Electroplating
B242 Guide for Preparation of High-Carbon Steel for Electroplating
B254 Practice for Preparation of and Electroplating on Stainless Steel
B281 Practice for Preparation of Copper and Copper-Base Alloys for Electroplating and Conversion Coatings
B322 Guide for Cleaning Metals Prior to Electroplating
B343 Practice for Preparation of Nickel for Electroplating with Nickel
B374 Terminology Relating to Electroplating
B481 Practice for Preparation of Titanium and Titanium Alloys for Electroplating
B482 Practice for Preparation of Tungsten and Tungsten Alloys for Electroplating
B487 Test Method for Measurement of Metal and Oxide Coating Thickness by Microscopical Examination of Cross Section

[1] This specification is under the jurisdiction of ASTM Committee B08 on Metallic and Inorganic Coatings and is the direct responsibility of Subcommittee B08.04 on Precious Metal Coatings.

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[2] The boldface numbers in parentheses refer to the list of references at the end of this specification.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

B488 Specification for Electrodeposited Coatings of Gold for Engineering Uses
B489 Practice for Bend Test for Ductility of Electrodeposited and Autocatalytically Deposited Metal Coatings on Metals
B499 Test Method for Measurement of Coating Thicknesses by the Magnetic Method: Nonmagnetic Coatings on Magnetic Basis Metals
B507 Practice for Design of Articles to Be Electroplated on Racks
B542 Terminology Relating to Electrical Contacts and Their Use
B558 Practice for Preparation of Nickel Alloys for Electroplating
B567 Test Method for Measurement of Coating Thickness by the Beta Backscatter Method
B568 Test Method for Measurement of Coating Thickness by X-Ray Spectrometry
B571 Practice for Qualitative Adhesion Testing of Metallic Coatings
B602 Test Method for Attribute Sampling of Metallic and Inorganic Coatings
B679 Specification for Electrodeposited Coatings of Palladium for Engineering Use
B689 Specification for Electroplated Engineering Nickel Coatings
B697 Guide for Selection of Sampling Plans for Inspection of Electrodeposited Metallic and Inorganic Coatings
B741 Test Method for Porosity In Gold Coatings On Metal Substrates By Paper Electrography (Withdrawn 2005)[4]
B748 Test Method for Measurement of Thickness of Metallic Coatings by Measurement of Cross Section with a Scanning Electron Microscope
B762 Test Method of Variables Sampling of Metallic and Inorganic Coatings
B765 Guide for Selection of Porosity and Gross Defect Tests for Electrodeposits and Related Metallic Coatings
B799 Test Method for Porosity in Gold and Palladium Coatings by Sulfurous Acid/Sulfur-Dioxide Vapor
B809 Test Method for Porosity in Metallic Coatings by Humid Sulfur Vapor ("Flowers-of-Sulfur")
D1125 Test Methods for Electrical Conductivity and Resistivity of Water
D3951 Practice for Commercial Packaging
E18 Test Methods for Rockwell Hardness of Metallic Materials
E112 Test Methods for Determining Average Grain Size

3. Terminology

3.1 *Definitions*—Many terms used in this specification are defined in Terminology B374 or B542.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *underplating, n*—a metallic coating layer between the basis metal or substrate and the topmost metallic coating. The thickness of underplating is usually greater than 1 µm. For high energy electrical contact the thickness may be 2.0 – 4.0 µm.

3.2.2 *significant surfaces, n*—defined as those normally visible (directly or by reflector) 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 suitable marked samples.

4. Classification

4.1 Orders for articles to be plated in accordance with this specification shall specify the plating system, indicating the basis metal, the thickness of the underplatings, the thickness of the palladium-cobalt coating, and the grade of the gold overplating according to Table 2 and Table 3.

5. Ordering Information

5.1 In order 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 standard.

5.1.2 The coating system including basis metal, thickness class and gold overplate grade (see 4.1 and Table 1 and Table 2).

5.1.3 Presence, type, and thickness of underplating (see 3.2.1).

5.1.4 Significant surfaces shall be defined (see 3.2.2).

5.1.5 Requirements, if any, for porosity testing (see 9.5):

5.1.6 Requirement, if any, for bend ductility testing (see 9.6):

5.1.7 Sampling plan employed (see Section 8), and

5.1.8 Requirement, if any, for surface coating cleanliness (absence of residual salts). See Appendix X3.

6. Materials and Manufacture

6.1 Any process that provides an electrodeposit capable of meeting the specified requirements will be 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.

TABLE 2 Thickness Class[A]

Thickness Class	Minimum Thickness of Pd-Co (µm)
0.08	0.08
0.15	0.15
0.25	0.25
0.50	0.50
0.75	0.75
1.00	1.00
1.25	1.25
1.5	1.5
2.5	2.5
3.0	3.0
5.0	5.0

[A]See X4.1 for specific applications of the various thickness classes.

[4] The last approved version of this historical standard is referenced on www.astm.org.

TABLE 3 Gold Overplate[A]

Grade	Type	MIL-G-45204	Hardness (Code)	Thickness Range
1	1 (99.9 % Au min)	III	90 HK_{25} max (A)	0.05-0.12 µm
2	2 (99.7 % Au min)	I	130-200 HK_{25} (C)	0.05-0.25 µm

[A]See Specification B488 and Appendix Appendix X1.

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 should be brought to the attention of the supplier and the purchaser (See Note 1).

6.2.3 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. The coatings must be smooth and as free of scratches, gouges, nicks, and similar imperfections as possible.

6.2.4 The base materials are to be cleaned and prepared as necessary to ensure good Pd-Co plating. The base material preparation may be accomplished in accordance with Practices B183, B254, B281, B322, B343, B481, B482, and B558, and Guide B242.

NOTE 1—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 Apply the coating after all basis metal preparatory treatments and mechanical operations on significant surfaces have been completed.

6.4 *Racking:*

6.4.1 Position parts to allow free circulation of solution over all surfaces (ASTM B507). The location of rack or wire marks in the coating should be agreed upon between the purchaser and supplier.

6.5 *Plating Process:*

6.5.1 *Nickel Underplating*—The nickel underplating (ASTM B689) must be applied before the palladium-cobalt alloy plating when the product is made from copper or copper alloy. Nickel underplatings are also applied for other reasons. See Appendix X2.

6.5.2 *Palladium-Cobalt Overplating*—The electrodeposition process produces mechanically stable Pd-Co films at current densities from less than 50 mA/cm^2 to greater than 700 mA/cm^2. It can produce alloys of 10 to 30 percent Cobalt content. Any desired composition (for example, 20% Co) cab be maintained within ±5 percent over a wide range of operating conditions and bath aging.

6.5.3 *Plating*—Good practice calls for the work to be electrically connected when entering the bath. A minimum of 0.5 V is suggested. During electroplating it is extremely important to maintain the voltage, current density, or both beneath the value for hydrogen evolution, if possible.

6.5.4 *Stress Cracking*—Problems associated with the incorporation of hydrogen in the palladium-cobalt, which can lead to stress cracking of the coating, shall be controlled by choosing plating baths and plating conditions that minimize the H/Pd-Co deposition ratio. The presence of stress-induced microcracks that penetrate to the underlying substrate or underplating can be detected with one of the porosity tests specified in 9.5.

6.5.5 *Gold Overplating*—A thin gold overplating after the palladium-cobalt can be applied in an application in which gold plated electrical connectors are mated together in a contact pair. This process is necessary to preserve the performance of the contact surface. See Appendix X1 for other reasons for using a gold overplate.

6.5.6 *Residual Salts*—For rack and barrel plating applications, 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 (racks) 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 where dwell times are significantly reduced. See Appendix Appendix X3.

7. Coating Requirements

7.1 *Coating Composition*—The preferred palladium-cobalt alloy composition should be 80% palladium and 20% cobalt; however the palladium (ASTM B679) content should never be less than 70% and the cobalt should never be more than 30%.

7.2 *Appearance*—Palladium-cobalt coatings shall be smooth, uniform and continuous in appearance with no cracks, pits, nodules, blisters, roughness, excessive edge buildup, areas of no plating, burned deposits or any other unwanted visible plating irregularity. The examination should be done with the unaided eye and under 10X magnification.

7.3 *Thickness*—Everywhere on the significant surface (see 5.1.4), the thickness of the palladium coating shall be equal to or exceed the specified thickness. The maximum thickness, however, shall not exceed the drawing tolerance (see Note 3 and Note 2).

NOTE 2—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 everywhere on the significant surfaces while conforming to all maximum thickness 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 will have to exceed the specified value at some points on the significant surfaces to ensure that the thickness equals or exceeds the specified value at all points. Hence, in most cases, the average coating thickness on an article will be greater than the specified value; how much greater is largely determined by the shape of the article (see Practice B507) and the characteristics of the plating process.

NOTE 3—In addition, the average coating thickness on articles will vary from article to article within a production lot. Therefore, if all of 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 assure that a single article meets the requirement.

7.4 *Adhesion*—The palladium-cobalt coatings shall be adherent to the substrate, when tested by one of the procedures summarized in 9.4.

7.5 *Integrity of the Coating:*

7.5.1 *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 of or on the periphery of the significant surfaces. See paragraphs 7.5.2 and 6.5.4.

7.5.2 *Porosity*—Almost all as-plated electrodeposits contain some porosity, and the amount of porosity to be expected for any one type of coating will increase with decreasing the thickness of that particular coating type. The amount of porosity in the coating that may be tolerable 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. 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 Note 4 and 9.5).

NOTE 4—Extensive reviews of porosity and porosity testing can be found in the literature (6, 7).

7.6 *Ductility*—The ductility of Pd-Co is a function of cobalt in the deposit. The ductility will decrease as the cobalt content increase. With Pd-Co composition of 80-20 the ductility measured per ASTM B489 should be 5 -7%. The ductility should never be less than 3% which is similar to hard gold.

8. Sampling

8.1 The sampling plan used for the inspection of a quality of the coated articles shall be as agreed upon between the purchaser and the supplier (See Note 5).

NOTE 5—Usually, when 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 or not 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 B602, Guide B697, and Test Method B762 contain sampling plans that are designed for the sampling inspection of coatings.

Test Method B602 contains four sampling plans, three for use with tests that are non-destructive and one when they are destructive. The buyer and seller may agree on the plan or plans to be used. If they do not, Test Method B602 identifies the plan to be used.

Guide B697 provides a large number of plans and also gives guidance in the selection of a plan. When Guide B697 is specified, the buyer and seller need to agree on the plan to be used.

Test Method B762 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. Test Method B762 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, Test Method B762 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 in not more than 8 hours, and that are submitted for acceptance or rejection as a group.

9. Test Methods

9.1 *Deposit Purity*—Use any recognized method to determine qualitatively the impurities present. Atomic absorption spectrophotometry (or any other 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 impurities. Determine deposit purity by subtracting total impurities from 100 % (See Note 6).

NOTE 6—Deposit purity is best determined on a special test specimen. One must be careful to arrange the specimen so as to electroplate at a typical density, similar to the production pieces. Palladium may be stripped by utilizing a 90 volume % (reagent grade) sulfuric, 10 % (reagent grade) nitric acid solution. The test specimen substrate should be platinum, gold, or an electrodeposit not attacked by the strip solution. The total palladium-cobalt deposit should be over 100 mg and the sample weight is determined by a weigh-strip-weigh procedure. The strip solution is then used for quantitative analysis of impurities.

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

9.3 *Thickness*—Measure thickness by methods outlined in Test Methods B487, B499, B567, B568, or B748, or any other test method that has an uncertainty less than 10 %, or less than the test methods listed.

9.4 *Adhesion*—Determine adhesion by one of the following procedures (see Practice B571 for full details):

9.4.1 *Bend Test*—Bend the electroplated article repeatedly through an angle of 180° on a diameter equal to the thickness of the article until fracture of the basis metal occurs. Examine the fracture at a magnification of 10×. Cracking without separation does not indicate poor adhesion unless the coating can be peeled back with a sharp instrument.

9.4.2 *Heat Test*—No flaking, blistering, or peeling shall be apparent at a magnification of 10× after the palladium-cobalt electroplated parts are heated to 300 to 400°C (570 to 750°F) for 30 min and allowed to cool.

9.4.3 *Cutting Test*—Make a cut with a sharp instrument and then probe with a sharp point and examine at a magnification of 10×. No separation of the coating from the substrate shall occur.

9.5 *Plating Integrity*—Porosity and microcracks shall be determined by either Test Methods B741, B799, or B809, unless otherwise specified. Do not use the nitric acid vapor test (palladium-cobalt alloy can dissolve in nitric acid.)

Note based on the type of base material, the type of underplating and its thickness, and the shape of the palladium-cobalt plated parts, Guide B765 can help determine the selection of the suitable porosity tests for electrodeposits of palladium-cobalt alloys.

9.6 *Ductility*—When required, determine ductility in accordance with Practice B489.

9.7 In the absence of an agreement between the purchaser and the supplier the following test requirements will apply.

9.7.1 Acceptance Testing – The appearance (9.2), thickness (9.3) and adhesion (9.4) must be performed for every lot (8.2).

9.7.2 *Periodic Testing*—The porosity (7.5.2) and palladium-cobalt plating alloy composition must be performed at least once a month, if applicable.

10. Special Government Requirements

10.1 The following special requirements shall apply when the ultimate purchaser is the U.S. Government or an agent of the U.S. Government.

10.1.1 *Sampling*—For government acceptance, the sampling plane specified in MIL-STD-105 is to be used instead of the ASTM standards specified in 8.1.

10.1.2 *Thickness Testing:*

10.1.2.1 In addition to the non-destructive methods outlined in Practice B499 and Test Methods B567 and B568, a crosssectioning method, such as that specified by Test Method B487 or B748, shall be used as a referee method to confirm the precision and bias of the particular non-destructive technique that is used.

10.1.2.2 The palladium-cobalt thickness on significant surfaces shall be at least 1.3 µm (0.05 mil) unless otherwise specified on the drawings or in the contract. The coating on nonsignificant surfaces shall be of sufficient thickness to ensure plating continuity and uniform utility, appearance, and protection. The thickness of plating on nonsignificant surfaces, unless specifically exempted, shall be a minimum of 60 % of that specified for significant surfaces.

10.1.3 *Packaging*—The packaging and packing requirements shall be in accordance with Practice D3951 or as specified in the contract or order. (**Warning**—Some contemporary packaging materials may emit fumes that are deleterious to the coating surface.)

11. Other Requirements

11.1 The need for the increasing use of palladium based finishes is driven by the requirements of high voltage, current and temperature for the Hybrid and Electrical Vehicles not readily met by hard gold. Palladium and palladium alloys, Pd-Ni and Pd-Co is becoming the preferred finish for high-temperature automotive applications. Palladium-nickel is not without its problems. Quality control issues related to the measurement of composition and thickness by simple, non-destructive x-ray fluorescence (XRF) analysis remain a significant concern. Palladium-cobalt on the other hand does not suffer from this shortcoming and has been found to outperform palladium-nickel for high-durability applications (2)[3].

12. Keywords

12.1 connectors; contacts; electrical connectors; electrical contacts; engineering coatings; palladium; palladium-cobalt coatings; palladium-cobalt electrodeposits; palladium-cobalt plating

APPENDIXES

(Nonmandatory Information)

X1. SOME REASONS FOR USING A GOLD OVERPLATE

X1.1 gold overplate is employed to enhance the performance of the palladium-cobalt surface, when the application temperature is less than 150°C

X1.2 The gold overplate offers the following performance enhancements to palladium-cobalt:

X1.2.1 *Durability*—A gold overplate of proper thickness can reduce friction and enhance durability by providing a low shear-strength solid lubricant that reduces friction and wear (8,9). Palladium- should not be mated against itself in a sliding contact pair when durability and resistance to fretting and frictional polymer formation is desired.

X1.2.2 *Mating Force*—Application of gold can reduce friction and mating force.

X1.2.3 *Fretting*—Fretting occurs when two surfaces undergo low amplitude, repetitive motions. Depending on conditions and contact surface materials, fretting wear or fretting corrosion can occur. Fretting wear is loss of material along the wear track. Fretting corrosion is the formation of surface oxides at the contact surface. The addition of gold can often reduce fretting corrosion that is due to fretting motions (10). The occurrence of fretting is influenced greatly by contact design. See Terminology B542.

X1.2.4 *Frictional Polymerization*—Frictional polymerization is the formation of insulating polymeric films at the contact spot. Such occurrences have been documented for palladium, palladium-nickel palladium-cobalt alloys and other metals (9). The addition of gold overplate can often reduce frictional polymer formation (10). (See Terminology B542.)

X2. SOME REASONS FOR USING A NICKEL UNDERPLATE FOR PALLADIUM-NICKEL ELECTROPLATING

X2.1 *Diffusion Barrier*—To inhibit diffusion of copper from the basis metal into the palladium-cobalt.

X2.2 *Levelling Layer*—To produce a smoother surface than the basis metal in order to ensure a lower porosity palladium-cobalt top coat, for example, levelling nickel over a rough substrate.

X2.3 *Pore Corrosion Inhibitor*—A nickel underplate under the palladium top coat will form passive oxides at the base of pores in humid air, provided the environment does not contain significant amounts of acidic pollutants, such as SO_2 or HCl.

X2.4 *Load Bearing Underlayer for Contacting Surfaces*—A hard nickel underplate can serve as a load bearing foundation for the palladium-cobalt top coat and reduce the wear of the precious metal during sliding of the contacting surfaces.

X2.5 For all of these purposes, the nickel underplating must be intact, that is, not cracked, and must have sufficient thickness to achieve the particular function for which it was intended. As a general rule, the minimum thickness should be 1.3 µm (50 µin.), preferably greater. For some levelling purposes, a greater thickness may be required.

X3. RESIDUAL SALTS

X3.1 Electroplated parts are placed in water of known conductivity and agitated for a specific time. The conductivity of the water extract is measured and the increase in conductivity due to residual salts and other conducting impurities is calculated. A suggested water extract conductivity test method uses a procedure in accordance with Test Methods D1125, Method A.

X3.2 Conductivity of water for extract test shall be 1 µS/cm or less (resistivity 1 MΩ·cm or more).

X3.2.1 A sample of the coated parts having a total surface area of 30 cm^2 shall ordinarily be used and extracted in 100 cm^3 of equilibrated water. To prepare equilibrated water, fill a clean polyethylene bottle half-way with high-purity water (X6.1), replace the bottle cap and shake the bottle vigorously for 2 min to equilibrate the water with the CO_2 in the air. CO_2 is a component of air, is soluble in water, and forms carbonic acid, which ionizes and is at equilibrium at 0.8 µS/cm. Slowly agitate the solution for 10 min before determining the conductivity of the extract. In a closed polyethylene bottle, the equilibrated water will remain in the range from 0.8 to 1 µS/cm for at least 1 week.

X3.3 Inspection under a source of ultraviolet light is often employed to determine whether electroplating salts have been removed by the rinsing following gold electroplating. The presence of salts is evidenced by a characteristic fluorescence and should not be confused with fluorescing dirt or dirt particles.

X3.4 Water or purging stains, resulting from blind holes or from parts that were assembled before electroplating, as normally obtained in good commercial practice, are permissible except where they occur on surfaces to which electrical contact is to be made or on which subsequent soldering operations are performed.

X4. RECOMMENDED THICKNESSES

X4.1 Palladium-cobalt thicknesses that have been recommended for specific applications are given in the following table.

Thickness, µm	Application
0.08–0.25	Semiconductor Lead Frames in Integrated Circuitry (11). Also solderable surfaces on Printed Wiring Boards
0.25–0.5	Catalysts. Also electrical contacts where little adverse environmental, electrical, or mechanical action is expected.
0.75–1.5	Low-energy electrical connector contacts.
1.2–2.0	High-energy electrical connector contacts with moderate mating cycles
2.0–4.0	High-energy electrical connector contacts with high mating cycles
2.5–5	Relay contacts with mechanical and electrical erosion.

REFERENCES

(1) J.A. Abbys, E. J. Kudrak & C. Fan, "The Materials Properties and Contact Reliability of Palladium- Cobalt", Trans IMF, 1999.

(2) J.A. Abys, C. F. Breck, H. K. Straschil, I. Boguslavsky, & G. Holmbom,"The electrodeposition & Material Properties of Palladium-Cobalt" Plating & Surface Finishing January 1999.

(3) Safranek, W. H., ed., Properties of Electrodeposited Metals and Alloys, AESF Soc., 2nd Ed., Orlando, FL, 1986.

(4) Abys, J., "The Electrodeposition and Material Properties of Palladium-Nickel Alloys," Metal Finishing, July, 1991

(5) Abys, J., Trans. Inst. Metal Finishing, Aug., 1987, p.23

(6) Clarke, M., "Porosity and Porosity Tests," Properties of Electrodeposits, Sard, Leidheiser, and Ogburn, eds., The Electrochemical Society, 1975, p. 122.

(7) Krumbein, S. J., "Porosity Testing of Contact Platings," Transactions of the Connectors and Interconnection Technology Symposium, ASTM, 1987, p. 47.

(8) Antler M, "Friction and Wear of Electrodeposited Palladium Contacts: Thin Film Lubricant with Fluids and Gold," IEEE Transactions, CHMT-9, No. 4, 1986 T.

(9) T. Sato, Y. Matsui, K. Murakawa and Z. Henmi, "Sliding Properties of Contacts Plated with Nickel, Palladium and Gold," Plating, Vol. 8, p 55, Aug., 1983.

(10) Bare and Graham, "Connector Resistance to Failure by Fretting and Frictional Polymer Formation," Proceedings of 31st IEEE Holm Conference on Electrical Contacts, 1984, p. 61-67.

(11) Abbott, D., Brook, R.M., McClelland, V., and Wiley, J.S., IEEE Trans. on Components, Hybrids, and Manufacturing Technol. Vol 14, No. 3, p. 567-572, Sept. 1991