Designation: B 700 – 97

Standard Specification for Electrodeposited Coatings of Silver for Engineering Use[1]

This standard is issued under the fixed designation B 700; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers requirements for electrodeposited coatings of silver used for engineering purposes that may be mat, bright, or semibright and are not less than 98 % silver purity.

1.2 Coatings of silver covered by this specification are usually employed for solderable surfaces, electrical contact characteristics, high electrical and thermal conductivity, thermocompression bonding, wear resistance of load-bearing surfaces, and spectral reflectivity.

1.3 In the Appendixes important characteristics of electrodeposited silver coatings are briefly described which must be considered when used in engineering applications, namely electrical conductivity (see Appendix X1), silver migration (see Appendix X2), thickness (see Appendix X3), hardness (see Appendix X4), and atmospheric tarnish (see Appendix X5).

1.4 The following hazards caveat pertains only to the test methods section of this specification: *This standard does not purport to address 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 183 Practice for Preparation of Low-Carbon Steel for Electroplating[2]
B 242 Practice for Preparation of High-Carbon Steel for Electroplating[2]
B 252 Guide for Preparation of Zinc Alloy Die Castings for Electroplating Conversion Coatings[2]
B 253 Guide for Preparation of Aluminum Alloys for Electroplating[2]
B 254 Practice for Preparation of and Electroplating on Stainless Steel[2]
B 281 Practice for Preparation of Copper and Copper-Base Alloys for Electroplating and Conversion Coatings[2]
B 322 Practice for Cleaning Metals Prior to Electroplating[2]
B 343 Practice for Preparation of Nickel for Electroplating with Nickel[2]
B 374 Terminology Relating to Electroplating[2]
B 481 Practice for Preparation of Titanium and Titanium Alloys for Electroplating[2]
B 482 Practice for Preparation of Tungsten and Tungsten Alloys for Electroplating[2]
B 487 Test Method for Measurement of Metal and Oxide Coating Thicknesses by Microscopical Examination of a Cross Section[2]
B 499 Test Method for Measurement of Coating Thicknesses by the Magnetic Method: Nonmagnetic Coatings on Magnetic Basis Metals[2]
B 504 Test Method for Measurement of Thickness of Metallic Coatings by the Coulometric Method[2]
B 507 Practice for Design of Articles to be Electroplated on Racks[2]
B 542 Terminology Relating to Electrical Contacts and Their Use[3]
B 567 Test Method for Measurement of Coating Thickness by the Beta Backscatter Method[2]
B 568 Test Method for Measurement of Coating Thickness by X-Ray Spectrometry[2]
B 571 Test Methods for Adhesion of Metallic Coatings[2]
B 578 Test Method for Microhardness of Electroplated Coatings[2]
B 579 Specification for Electrodeposited Coatings of Tin-Lead Alloy (Solder Plate)[2]
B 602 Test Method for Attribute Sampling of Metallic and Inorganic Coatings[2]
B 678 Test Method for Solderability of Metallic-Coated Products[2]
B 697 Guide for Selection of Sampling Plans for Inspection of Electrodeposited Metallic and Inorganic Coatings[2]
B 762 Method of Variables Sampling of Metallic and Inorganic Coatings[2]
B 849 Specification for Pre-treatments of Iron or Steel for Reducing the Risk of Hydrogen Embrittlement[2]
B 850 Specification for Post-Coating Treatments of Iron or Steel for Reducing the Risk of Hydrogen Embrittlement[2]
D 3951 Practice for Commercial Packaging[4]
E 1004 Test Method for Electromagnetic (Eddy-Current)

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[2] *Annual Book of ASTM Standards*, Vol 02.05.

[3] *Annual Book of ASTM Standards*, Vol 03.04.

[4] *Annual Book of ASTM Standards*, Vol 15.09.

Measurements of Electrical Conductivity[5]
F 519 Method for Mechanical Hydrogen Embrittlement Testing of Plating Processes and Aircraft Maintenance Chemicals[6]

3. Terminology

3.1 *Definitions*—Many of the terms used in this specification are defined in Terminologies B 374 or B 542.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *rack-plating*—an electrodeposition process in which articles to be coated are mounted on racks or other fixtures during the process.

3.2.2 *significant surfaces*—surfaces that are normally visible, directly or by reflection, or that are essential to the serviceability or function of the article or which can be the source of corrosion products or tarnish films that interfere with the function or desirable appearances of the article. When necessary, the significant surfaces shall be indicated on the drawings of the parts, or by the provisions of suitably marked samples.

3.2.2.1 *Discussion*—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. The average coating thickness on the article usually will be greater than that specified; how much greater is largely determined by the shape of the article (see Practice B 507) and the characteristics of the electroplating process. Additionally, the average coating thickness on an article will vary from article to article within a production lot. If all the articles in a production lot are to meet the thickness requirement, the average coating thickness of a production lot as a whole will be greater than the average necessary to ensure that a single article meets requirements.

3.2.3 *strike or flash*—a thin, typically less than 0.25-µm (10 µ-in.) metallic coating layer between metallic coatings to improve adhesion.

3.2.4 *underplating*—an application of a metallic coating layer between the basis metal or substrate and the topmost metallic coating or coatings (see 6.3.4).

4. Classification

4.1 Electrodeposited coatings of silver shall be classified for *Type* based on minimum purity, *Grade* whether bright, semibright, or mat, *Class* if supplementary surface treatment is applied, and thickness in micrometers.

4.2 *Purity*—Specify by *Type* as follows:

Type 1—99.9 % min
Type 2—99.0 % min
Type 3—98.0 % min

NOTE 1—Metallic or organic brighteners used for grain refinement may be present in the electrodeposit so long as they do not interfere with the stated function of the coating and are acceptable to the purchaser (see Appendix X1).

[5] *Annual Book of ASTM Standards*, Vol 03.03.
[6] *Annual Book of ASTM Standards*, Vol 15.03.

4.3 *Surface Appearance*—Specify by *Grade* in letter code as follows:

Grade A, Mat—Electrodeposits without luster, obtained from electroplating solutions operated without the use of brighteners.

Grade B, Bright—Electrodeposits obtained by the use of brighteners in the electroplating bath.

Grade C, Bright—Electrodeposits obtained by mechanical or chemical polishing of *Grade A* silver coatings.

Grade D, Semibright—Electrodeposits obtained by the use of addition agents in the electroplating bath.

4.4 *Supplementary Surface Treatment*— Specify by *Class* in letter code as follows:

Class N—A finish that has had no supplementary tarnish resistant (that is, chromate) treatment (see Appendix X5).

Class S—A finish that has had a supplementary tarnish resistant (that is, chromate) treatment.

NOTE 2—*Class S* is not suitable for food service applications.

5. Ordering Information

5.1 To make 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 Name, designation, and year of issue of this standard.

5.1.2 Type (see 4.2), Grade (see 4.3), Class (see 4.4) and Thickness (see 6.6 and Appendix X3).

5.1.3 *Nature of Substrate*—If, for example, it is high strength steel, the need for stress relief (see 6.3.2.1) and embrittlement relief (see 6.3.5.1). If it is copper, an undercoat is needed (see S1.3) for some applications.

5.1.4 *Significant Surfaces* (see section 3.2.2).

5.1.5 *Appearance* (see 6.7).

5.1.6 *Underplates* (see 6.3.4 and S1.3).

5.1.7 Requirements and methods of testing for one or more of the following: need for and type of test specimens (see 8.1), thickness (see 6.6, 8.2, and Appendix X3), adhesion (see 6.8 and 8.3), hardness (see 6.10.1 and 8.7), absence of embrittlement (see 8.4), solderability (see 6.9 and 8.5), spectral reflectance (see 6.10.2 and 8.8), or electrical conductivity (see 6.10.3 and 8.9).

5.1.8 *Sampling Plans and Quality Assurance* (see Section 7 and S1.2).

6. Coating Requirements

6.1 *Nature of Coating*—The coating essentially shall be silver, considering the type specified, produced by electrodeposition from aqueous electrolytes.

6.2 *Purity of Coating*—The coating shall meet the chemical composition requirements of the specified type as defined in 4.2 and measured as described in 8.6.

6.3 *Process*:

6.3.1 The basis metal shall be subjected to such cleaning procedures as are necessary to ensure a surface satisfactory for subsequent electroplating. Materials used for cleaning shall have no damaging effects on the basis metal resulting in pits, intergranular attack, stress corrosion cracking, or hydrogen embrittlement.

NOTE 3—For basis metal preparations, the following appropriate

ASTM standards are recommended: Practices B 183, B 242, B 252, B 254, B 281, B 322, B 343, B 481, and B 482, and Guide B 253.

6.3.2 *Preplating Operations*—Electroplating shall be applied after all basis metal heat treatments and mechanical operations such as forming, machining, and joining of the article have been completed.

NOTE 4—Silver deposits may be used to facilitate mechanical operations such as forming and drawing. In these applications, silver is applied before such process steps.

6.3.2.1 *Stress Relief Treatment*—Parts that are made of steels with ultimate tensile strength of 1000 MPa or over (hardness of 31 HRC or greater) that have been machined, ground, cold-formed or cold-straightened subsequent to heat treatment, may require stress relief heat treatment when specified by the purchaser, the tensile strength to be supplied by the purchaser. Specification B 849 may be consulted for a list of pretreatments that are used widely.

6.3.3 *Strike*—The final silver coating shall be preceded by a silver or gold strike for optimum adhesion.

6.3.4 *Underplating*—A nickel or nickel-alloy intermediate layer, at least 1 µm thick, shall be applied before the silver electroplate when the product being plated is made from copper or copper alloy. Nickel underplatings are also applied for other reasons.

6.3.5 *Post-Plating Procedures*:

6.3.5.1 *Embrittlement Relief*—Parts that are made of steels with ultimate tensile strength of 100 MPa or over (hardness of 31 HRC or greater), as well as surface-hardened parts, may require post-coating hydrogen embrittlement relief baking when specified by the purchaser, the tensile strength to be supplied by the purchaser. Specification B 850 may be consulted for a list of post-treatments that are used widely.

6.4 *Surface Appearance*—The coating's surface finish shall meet the requirements of the specified grade defined in 4.3.

6.5 *Supplementary Post Treatment*—The coating shall meet the requirements of the specified class defined in 4.4.

6.6 *Thickness*—The silver coating thickness on significant surfaces shall be at least that specified (see Appendix X3) when measured as described in 8.2.

6.7 *Appearance*—Silver electroplated coated articles shall be covered completely on all surfaces as specified in the manufacturing document and shall have a uniform appearance with no visible defects to the extent that the nature of the basis metal and good commercial practice permit. The requirement for uniform color or appearance need not apply for subsequent passivation or other treatments of the silver.

6.7.1 *Defects*—Defects in the surface of the basis metal such as scratches, pits, non-conducting inclusions, and roll and die marks may adversely affect the appearance and performance of applied coatings. Such defects that persists in the finish despite the observance of good metal finishing practices shall not be cause for rejection.

NOTE 5—Coated finishes generally perform better in service when the substrate over which they are applied is smooth and free from torn metal, inclusions, pores, and other defects. It is recommended that the specifications covering the unfinished product provides limits for those defects. A metal finisher often can remove defects by means of special treatments such as grinding, polishing, abrasive blasting, chemical treatments, and electropolishing. However, these are not normal for the treatment steps preceding application of the finish. When they are desired, they are the subject of special agreement between the purchaser and the supplier.

6.8 *Adhesion*—The silver coatings shall be free of blisters and peeled areas indicating poor adhesion when tested in accordance with 8.3.

NOTE 6—Some applications may require no separation by any mechanical means such as machining or milling through the interface.

6.9 *Solderability*—The silver plated surfaces shall produce solder coatings which shall be bright, smooth, and uniform. At least 95 % of the sample surface shall show good wetting when tested as described in 8.5.

6.10 *Supplementary Requirements*:

6.10.1 *Hardness*—If a hardness requirement is specified, the hardness of the silver coatings shall conform to that specified as measured as described in 8.7.

6.10.2 *Spectral Reflectance*—The spectral reflectance of the silver coatings, if required, shall conform to that specified when measured as described in 8.8.

6.10.3 *Electrical Conductivity*—The electrical conductivity of the silver coatings, if required, shall conform to that specified when measured as described in 8.9.

7. Sampling

7.1 A random sample of the size required by Test Method B 602 or Method B 762 shall be selected from the inspection lot (see 7.2). The articles in the lot shall be classified as conforming or nonconforming to each requirement according to the criteria of the sampling plans in the chosen method.

NOTE 7—Test Method B 602 contains four sampling plans, three for use with nondestructive test methods; the fourth is for use with destructive test methods. The three methods for nondestructive tests differ in the quality level they require of the product. Test Method B 602 requires use of the plan with the intermediate quality level unless the purchaser specifies otherwise. It is recommended that the purchaser compare the plans with his needs and state which plan is to be used. If the plans in Test Method B 602 do not serve the needs, additional ones are given in Guide B 697 which provides a large number of plans and also gives guidance in the choice of a plan. When Guide B 697 is specified, the buyer and seller need to agree on the plan to be used.

NOTE 8—Method B 762 is a variables sampling plan. Such plans can only be used when a test yields a measured quantity, such as thickness, and when the requirements are stated as a numerical unit also such as thickness. Method B 762 contains several plans for special needs. Buyer and seller may agree on the plan or plans to be used; if not, Method B 762 identifies the plan to be used.

NOTE 9—When both destructive and nondestructive tests exist for the measurement of a characteristic, the purchaser needs to state which is to be used so the proper sampling plan is selected. Whether or not a test is destructive may not always be clear. A test may destroy the coating but in a noncritical area. The purchaser needs to state whether the test is to be considered destructive or nondestructive. The decision is important because the plans for destructive tests are significantly less able to discriminate between acceptable and unacceptable lots. This is because fewer parts are tested.

7.2 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 approximately the same time under essentially identical conditions, and that are submitted for acceptance or rejection as a group.

7.3 If special test specimens are used to represent the coated articles in a test, the specimens shall be of the nature, size, and number and shall be processed as required in 8.1.

8. Test Methods

8.1 *Special Test Specimens*:

8.1.1 Special test specimens are used to represent the coated articles in a test if the articles are of a shape, size or material that is not suitable for the test, or if it is preferred not to submit samples to a destructive test because, for example, they are expensive or few in number. The permission or requirement to use special test specimens, their number, the material they are to be made of, and their size and shape shall be stated by the purchaser.

8.1.2 The special test specimen shall duplicate those characteristics of the article that influence the property being tested; and it shall be processed with the article through those process steps that influence the property.

8.1.3 The special test specimens used to represent an article in an adhesion, solderability, or appearance test shall be made of the same material, shall be in the same metallurgical condition, and shall have the same surface condition as the articles they represent. They shall be placed in the production lot of and be processed along with the articles they represent.

8.1.4 Special test specimens used to represent an article in a coating thickness test shall be introduced into the process at the point where the coatings are applied and shall be carried through all the steps that have a bearing on the coating thickness.

NOTE 10—When special test specimens are used to represent a coated article in a thickness test, the specimens will not necessarily have the same thickness and thickness distribution as the article unless the specimens and the articles are of the same general size and shape. Therefore, before coated articles may be accepted on the basis of a thickness test performed on test specimens, the relationship between the thickness on special test specimens and the thickness on the part needs to be established. The criterion of acceptance is that the thickness on the specimen corresponds to the required thickness on the articles.

8.2 *Thickness*—The coating thickness shall be measured at locations on significant surfaces where it would be expected to be a minimum either nondestructively or destructively:

8.2.1 *Nondestructive*—Measure thickness of silver coatings by beta backscatter (Test Method B 567), by X-ray spectrometry (Test Method B 568), or by the magnetic method (Test Method B 499).

8.2.2 *Destructive*—Measure thickness of silver coatings by the coulometric technique (Test Method B 504) or by microscopical cross-sectioning procedures (Test Method B 487).

8.3 *Adhesion*—Determine adhesion qualitatively with one of the procedures given in Test Methods B 571. Other procedures, such as machining milling, or shot peening may prove more appropriate in special cases.

8.4 *Hydrogen Embrittlement Relief*— Steel products that are required as described in 6.3.5.1 to be heat treated to remove hydrogen embrittlement shall be evaluated as directed by Method F 519 as a means of evaluating the process, using special test specimens (see 8.1).

8.5 *Solderability*—Determine solderability qualitatively by Test Method B 678.

NOTE 11—Other useful tests may be found in Specification B 579.

8.6 *Purity of Coating*—Obtain the composition of the silver coating by determining the impurities (that is silver by difference) by emission spectroscopy, x-ray fluorescence, atomic absorption, or other methods capable of determining quantities of 0.01 mass % or less.

8.7 *Hardness*—Measure low load microhardness in accordance with Test Method B 578 (see Appendix X4).

8.8 *Specular Reflectance*—Measure reflectance in the spectral region of 0.60 ± 0.05 µm on a coated surface using a device suitable for determinations at an angle of 45° employing a narrow acceptance angle (suited for mirror finishes).

8.9 *Electrical Conductivity*—Measure electrical conductivity by Test Method E 1004 using separate test specimens.

9. Packaging

9.1 Some packaging materials may emit fumes that can be deleterious to the appearance or performance, or both, of electroplated silver surfaces. Useful guidelines for commercial packaging can be found in Specification D 3951.

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 plan is to be in accordance with ANSI/ASQC Z1.4.

10.1.2 *Quality Assurance:*

10.1.2.1 *Inspection Responsibility*—The producer or supplier shall be responsible for the performance of all inspection and test requirements specified herein. Except as otherwise specified in the contract or order, the producer or supplier may use his own or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless disapproved by the purchaser. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification where such inspections are deemed necessary to assure the material conforms to the prescribed requirements.

10.1.3 *Undercoats*—The silver electroplating shall be applied over an intermediate coating of nickel or nickel over copper on steel, zinc, and zinc base alloys. Copper and copper base alloys require intermediate coatings. Copper alloy basis metal articles on which a nickel undercoat is not used and other basis metal whereon a copper undercoat is employed shall not be used for continuous service in excess of 149°C.

10.1.4 *Packaging*—Parts plated for the U.S. Government and Military, including as subcontracts, shall be packaged in accordance with Practice D 3951.

APPENDIXES

(Nonmandatory Information)

X1. ELECTRICAL RESISTIVITY

X1.1 The electrical resistivity of silver deposits will vary with the type of silver electrolyte used. The resistivity will be generally in the range from 0.017 to 0.020 μΩ·m. Resistivity of pure silver is 0.0162 μΩ·m. Sulfur- and selenium-containing electrolytes yield deposits having resistivity values 10 to 15 % higher than that of pure silver; those of antimony-brightened deposits can be substantially higher than that of pure silver. Periodic reverse current has been reported to yield deposits with about 1 % higher resistivity than the International Annealed Copper Standard versus about 6 % higher than IACS for deposits produced by direct current alone.[7]

[7] Luce, B. M., and Foulke, D. G., *Modern Electroplating*, F. A. Lowenheim, ed., John Wiley and Sons, Inc., New York, NY, 1974, pp. 371–372.

X2. SILVER MIGRATION

X2.1 When silver coatings are used as electrical conductors they may be susceptible to electromigration effects. Silver migration refers to the electrochemical transport of the metal from one conductor to another under the influence of an applied d-c electrical field. It can occur whenever the insulator separating the polarized (or *biased*) conductors (as on PC boards, flexible circuitry, chip carriers, or IC ceramics) has acquired sufficient moisture to allow electrolytic (ionic) conduction to occur.

X2.1.1 In the simplest case, metallic silver on the conductor with the more positive potential (anode) is oxidized to a more soluble form. The resulting positively-charged ions then move under the influence of the field through moisture paths on or in the insulator toward the more negative conductor (cathode), where they are reduced back to silver metal (Fig. X2.1).

X2.1.2 In practice, electromigration can produce two separate, but not always distinct, phenomena, both of which can lead to impairment of a circuit's electrical integrity. These are *silver staining*and filamental or dendritic bridging. Colloidal silver deposits appear as brownish stains on insulator areas where migrating silver ions have been chemically or photolytically reduced to metallic silver before they are able to reach the cathode. Silver dendrites, on the other hand, result from the fact that the ions tend to deposit at localized sites on the cathode in the form of needles or spikes. Once these nuclei have formed, the higher current density at their tips will greatly increase the probability of further deposition. This shows up as an accelerated growth outward from the tips in the form of thin black filaments of silver, extending from the cathode back toward the positive conductor. In the course of this growth, branching usually occurs at definite crystallographic angles, resulting in a characteristic *dendritic* structure.

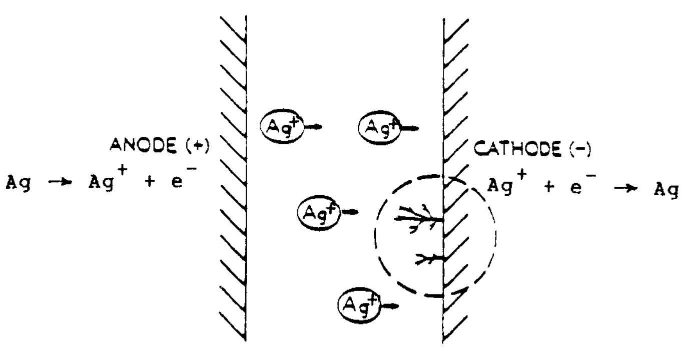

FIG. X2.1 Schematic Diagram of Early Stage of Dendrite Growth

X2.1.3 When a filament finally bridges the gap between polarized conductors, a sudden drop in electrical resistance will occur. Although the magnitude of the initial resistance drop will be small (because of the small cross-sectional area of a single filament), a rapid increase in additional bridges will soon lower the resistance sufficiently to produce circuit failures. Bridging also can be produced by colloidal silver deposits, especially at temperatures above 70°C and on contaminated surfaces.

X2.1.4 The primary operating parameters that promote electromigration problems are:

X2.1.4.1 Moisture (that is, high relative humidity),

X2.1.4.2 Contamination on the insulator surface,

X2.1.4.3 Voltage difference between conductors,

X2.1.4.4 Narrow spacing widths between conductors, and

X2.1.4.5 Elevated temperatures coupled with high relative humidity. The tendency towards electromigration also depends upon the nature of the insulator material and its surface condition as well as on the type of silver plating used. All of these factors are discussed in a 1988 publication.[8]

[8] Krumbein, S. J., IEEE TRANS Components, *Hybrids and Manufacturing Technology*, 11, No. 1, Mar. 1988, pp. 5–15.

X3. SILVER COATING APPLICATIONS

TABLE X3.1 Thickness

Application	Thickness, µm
Minimum for short-term shelf life solderability	1
Minimum for contact connectors having limited wear	2.5
Nominal thickness for thermocompression bonding and nominal thickness for domestic hollowware	5
Medium-quality hollowware, short-life domestic cutlery and flatware, and suggested thickness for thermocompression bonding and die attachment for semiconductors	10
Normal hotel flatware and high-quality domestic flatware and hollowware	20
Applications where very severe wear resistance is required, such as machine bearings and for high-quality flatware	≥40

X4. HARDNESS

X4.1 The hardness of unalloyed silver deposits is much higher than that for annealed wrought silver, probably due to a fine grain size. Electrolyte composition, operating parameters, and deposition conditions affect hardness, as well as the presence of small amounts of organic and inorganic brighteners and alloying elements.[9]

[9] Safranek, W. H., *The Properties of Electrodeposited Metals and Alloys*, 2nd. ed., American Electroplaters and Surface Finishers Society, Orlando, FL, 1986.

X5. SILVER TARNISH

X5.1 Silver readily forms creeping sulfide tarnish films in sulfur-containing environments. Free sulfur present from certain rubber compounds and cardboard materials cause growth of silver sulfide films at rapid rates. Such films create high electrical contact resistance and decrease solderability of silver surfaces. Anti-tarnish treatments are helpful though not completely effective.

X5.2 Anti-tarnish treatments commercially available include electrolytic processes based on chromates, immersion processes based on various film-forming organic compounds; and immersion tinplates. Process parameters and degree of protection afforded by these various treatments vary widely. There also are available various packaging materials that incorporate volatile organic compounds, which provide so-called vapor barrier protection when in contact or close proximity to silver surfaces.