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Standard Specification for Autocatalytic Nickel over Autocatalytic Copper for Electromagnetic Interference Shielding[1]

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1. Scope

This specification presents the requirements for multilayer coatings of autocatalytic nickel-phosphorus over autocatalytic copper on metallic and polymeric substrates. The coating system is intended to provide electromagnetic interference (EMI) protection properties or electrostatic discharge (ESD) protection to parts fabricated from either polymeric or metallic materials.

2. Referenced Documents

2.1 *ASTM Standards:*

A 919 Terminology Relating to Heat Treatment of Metals[2]

B 183 Practice for Preparation of Low-Carbon Steel for Electroplating[3]

B 242 Practice for Preparation of High-Carbon Steel for Electroplating[3]

B 252 Guide for Preparation of Zinc Alloy Die Castings for Electroplating and Conversion Coatings[3]

B 253 Guide for Preparation of Aluminum Alloys for Electroplating[3]

B 320 Practice for Preparation of Iron Castings for Electroplating[3]

B 322 Practice for Cleaning Metals Prior to Electroplating[3]

B 374 Terminology Related to Electroplating[3]

B 504 Test Method for Measurement of Thickness of Metallic Coatings by the Coulometric Method[3]

B 532 Specification for the Appearance of Electroplated Plastic Surfaces[3]

B 533 Test Method for Peel Strength of Electroplated Plastics[3]

B 553 Test Method for Thermal Cycling of Electroplated Plastics[4]

B 554 Practice for Measurement of Thickness of Metallic Coatings on Nonmetallic Substrates[5]

B 567 Test Method for Measurement of Coating Thickness by the Beta Backscatter Method[3]

B 568 Test Method for Coating Thickness by X-Ray Spectrometry[3]

B 602 Test Method for Attribute Sampling of Metallic and Inorganic Coatings[3]

B 697 Guide for Selection of Sampling Plans for Inspection of Electrodeposited Metallic and Inorganic Coatings[3]

B 727 Practice for Preparation of Plastics Materials for Electroplating[3]

B 733 Specification for Autocatalytic Nickel-Phosphorus Coatings on Metals[3]

D 3330/D 3330M Test Methods for Peel Adhesion of Pressure-Sensitive Tape at 180° Angle[6]

D 3359 Test Methods for Measuring Adhesion by Tape Test[7]

D 4935 Test Method for Measuring the Electromagnetic Shielding Effectiveness of Planar Materials[8]

2.2 *Military Standard:*

MIL-STD-461 Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference[9]

3. Terminology

3.1 *Definitions*—Many of the terms used in this specification can be found in Terminologies A 919 or B 374.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *significant surfaces, n*—these surfaces are classified as primary, secondary, nonsignificant, and coating-free surfaces.

3.2.1.1 *coating-free areas, adj*—areas specified on part drawings or suitably marked samples.

3.2.1.2 *nonsignificant surfaces, adj*—all holes, recesses, and other areas where a controlled deposit cannot be obtained under normal coating conditions and that cannot be touched with a 20-mm diameter ball shall be considered nonsignificant surfaces unless otherwise specified on part drawings or suitably marked samples.

3.2.1.3 *primary significant surface, adj*—all mating surfaces and those other surfaces specified on part drawings or suitably marked samples.

3.2.1.4 *secondary significant surfaces, adj*—all surfaces,

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[2] *Annual Book of ASTM Standards*, Vol 01.01.

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

[4] Discontinued 1992; see *1991 Annual Book of ASTM Standards*, Vol .

[5] Discontinued 1987; Replaced by B 659.

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

[7] *Annual Book of ASTM Standards*, Vol 06.01.

[8] *Annual Book of ASTM Standards*, Vol 10.02.

[9] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave. Philadelphia, PA 19111–5094, Attn: NPODS.

other than primary significant surfaces, that can be touched with a 20-mm diameter ball shall be considered secondary significant surfaces unless otherwise specified on part drawings or suitably marked samples.

4. Classification

4.1 This classification system provides for the following:

4.1.1 Types of coating based on thickness and testing requirements, and

4.1.2 Grades of coating based on alloy composition.

4.2 *Coating Type*:

4.2.1 The coating type indicates the type of application and tests to be used in determining the acceptance of the coating.

4.2.2 *Coating Type Definitions*:

4.2.2.1 *Type 1*—Coatings intended to shield devices for FCC/VDE Class B service.

4.2.2.2 *Type 2*—Coatings intended to shield devices for FCC/VDE Class B service in harsh environments.

4.2.2.3 *Type 3*—Coatings intended to shield devices for MIL-STD-461 requirements.

4.2.2.4 *Type 4*—Coatings intended to shield devices for FCC/VDE Class A requirements.

4.2.3 The description of Types 1, 2, 3, and 4 is summarized in Table 1.

4.3 *Coating Grade*:

4.3.1 The coating grade is based upon phosphorus content.

NOTE 1—The coating grade indicates the relative contact impedance and the relative corrosion resistance of the nickel-phosphorus coating and tests to be used in determining the acceptance of the coating

4.3.2 *Coating Grade Definitions*:

4.3.3 Grade 1 coatings have a phosphorus content between 3 and 5 %.

NOTE 2—Low phosphorus coatings exhibit low electrical contact impedance. High phosphorus contents exhibit somewhat higher contact impedance, however, the coating is more corrosion resistant.

4.3.4 Grade 2 coatings have a phosphorus content between 6 and 11 %.

NOTE 3—The adhesion and resistance to blistering are improved on some polymeric substrates by an initial flash deposit of autocatalytic nickel.

5. Ordering Information

5.1 To avoid misunderstanding between contractual parties, purchase orders or contracts for autocatalytic nickel over autocatalytic copper coatings under this specification should include the designation, issue date, and the following information:

5.1.1 Type of substrate.

5.1.1.1 Metallic substrates should state the composition and metallurgical condition. Assemblies of dissimilar materials should be identified.

5.1.1.2 Polymeric substrates should state the polymer type and should be of a plating grade.

5.1.2 Classification of the deposit by type and grade.

5.1.3 Primary significant surfaces and coating-free surfaces must be indicated on drawings.

5.1.4 Any special requirements.

5.1.5 Test methods for coating adhesion, thickness, porosity.

5.1.6 Sampling program.

TABLE 1 Autocatalytic Nickel-Phosphorus Over Autocatalytic Copper Coating Descriptions Summary

Type	Thickness		Shielding Effectiveness (Typical) per Test Method D 4935	Application
	Autocatalytic Copper	Autocatalytic Nickel-Phosphorus		
1	1 µm min	0.25 µm min	80-100 dB	FCC/VDE Class B
2	1 µm min	1.5 µm min	80-100 dB	Harsh Environment
3	2.5 µm min	0.25 µm min	90-110 dB	MIL-STD-461B
4	Optional/Not required	1.0 µm min	50-70 dB	FCC/VDE Class A

6. Surface Preparation

6.1 *Surface Contamination*—Surfaces of polymeric parts must be free of all mold release agents, dirt, oil, grease, and contamination detrimental to the final finish. Surfaces of metallic parts must be free of all scale, oxidation, and contamination detrimental to the final finish. A clean surface is essential to the adhesion and electrical conductivity requirements of the subsequent coated part.

6.2 *Cleaning, Conditioning, and Activating*—Any adequate method of cleaning, conditioning, and activating is acceptable provided the coated parts meet the inspection requirements and are free of distortion. Examples of adequate methods of cleaning can be found in 10.2.

6.2.1 *Base Material Suitability*—The parts to be coated shall be inspected by the coater prior to any processing to determine their suitability for coating. Unsuitable parts shall be returned to the fabricator or molder.

6.3 *Mechanical Roughening*—Mechanical roughening of polymer surfaces, to promote adhesion, may only be used when specified on the part drawing.

7. In-Process Storage and Handling

7.1 Following cleaning, conditioning, and activating, all parts shall be immediately coated with copper and then nickel-phosphorus to the thickness specified in Table 1. The parts processing cycle shall be a continuous operation without any interruption.

7.2 *Handling*—The parts shall be suitably racked so as to prevent gas entrapment and to avoid physical handling of the primary significant surfaces.

7.3 *Drying*—Following coating, the parts may be dried with warm air currents. Drying temperature shall not exceed the heat distortion temperature of the substrate. Wetting agents may be used to enhance water shedding provided they do not interfere with subsequent paint adhesion.

7.4 *Storage*—Following drying, all parts shall be stored in a clean dry area, protected from corrosive fumes and humidity prior to packaging and shipment.

8. Inspection

8.1 *Process Qualification*—All nickel-phosphorus over copper coatings shall be produced from processes qualified in accordance with the requirements in Section 9.

8.2 *Nickel-Phosphorus Over Copper Coating*—The nickel-phosphorus coating shall meet the requirements of Specification B 733.

8.2.1 *Appearance*—The nickel-phosphorus over copper coating shall be smooth, semi-bright, adherent, and free from defects that will impair the corrosion resistance, electrical conductivity or electromagnetic shielding effectiveness properties of the coating, see ASTM B 532 for polymeric parts and Specification B 733 for metallic parts.

8.2.2 *Blisters and Unplated Areas*

8.2.2.1 *Blisters*—The parts shall be examined visually for 10 to 15 s or as necessary to adequately examine the entire plated surface at a distance of 600 to 900 mm (arms length) for evidence of blisters. Visually means 20/20 vision or corrected to 20/20. Parts exhibiting blisters shall be rejected.

8.2.2.2 *Unplated Areas*—Voids, skips, and other unplated areas, visible to the unaided eye, exposing the substrate shall be limited to the sizes and numbers shown in Table 2. Voids and skips exposing copper are not permitted.

8.2.3 *Thickness*—The thickness test shall be performed on the primary and secondary significant surfaces of the finished part. Thickness shall be as specified in Table 1. For parts acceptance the combined thickness of deposit and tolerance specified in Table 1 may be used, provided representative parts also meet the electrical conductivity requirements specified in 8.2.5. The thickness of deposit on nonsignificant surfaces shall be that which results from control on the primary and secondary significant surfaces, provided plating coverage occurs, unless otherwise specified on the part drawing.

8.2.3.1 *Thickness Test Methods*—The following test methods are suitable for measuring local thickness of nickel-phosphorus and copper coating, see Practice B 554. See 8.2.3.2 for restrictions.

Coulometric Method—See Test Method B 504

X-Ray Method—See Test Method B 568

Beta Backscatter Method—See Test Method B 567

(a) *Coulometric Method*—This semi-destructive method is suitable for the measurement of individual layers in the range of 0.25 to 100 µm.

(b) *X-Ray Method*—This nondestructive method is suitable for the measurement of individual layers in the range of 0.25 to 65 µm and shall be the referee method.

(c) *Beta Backscatter Method*—This nondestructive method is suitable for measuring total coating thickness between 0.1 and 100 µm.

8.2.3.2 *Restriction*—Electronic thickness testers utilizing the Eddy-current principle are not suitable for this specification and shall not be used.

8.2.4 *Adhesion*—The coatings shall not peel or separate from the base material when subjected to the tape test (see 9.4.1).

8.2.5 *Electrical Continuity*—The coating shall form a continuous electrical path across the significant and nonsignificant surfaces.

8.2.5.1 *Electrical Criteria*—The DC resistance of the coating system, between all points of the primary significant surfaces shall not exceed 0.1 Ω unless otherwise specified on part drawings. The measurement shall be made with an ohmmeter, having a sensitivity of at least 20 000 Ω/V, and a measuring voltage of 9 ± 3 V DC and a 2 A load.

8.2.5.2 *Electrical Measurement Procedure*—The DC resistance of the coating system, shall be measured on a test sample prepared by assembling two coated parts together, clamping them with 2 M4, class 4.8 threaded fasteners assembled with two flat washers and a mating nut torqued to 1.5–2.0 NM. The measuring probes shall each be pressed firmly into the opposing faces of the assembly so as to make intimate contact with the coating. Alternatively, when it is not practical to assemble two parts together for this test, a single part may be used. In that event, press one probe firmly into the surface of the part so that it is in intimate contact with the coating. The second probe shall be held in contact with the part surface, in a position and with a pressure approximating that of writing with a pencil. This probe shall have a radius of 1 mm minimum. The probes shall be held at least 25 and no more than 200 mm apart.

8.3 *Sampling*—A suitable sampling plan may be selected from those in Test Method B 602. Guidance in selecting a suitable sampling plan will be found in Guide B 697.

TABLE 2 Allowable Unplated Areas

Area	Size/Void, max	Maximum Void Area/10 000 mm^2
Mating surface areas	0	0
Nonmating surface area	100 mm^2	200 mm^2

9. Requirements for Process Qualification

9.1 *Process Selection*—Commercial processes are available that meet the requirements of this specification.

9.2 *Coating Composition*—The composition of the nickel-phosphorus coating shall be 3 to 11 % phosphorus and the remainder nickel. The composition of the copper coating shall be 99 % copper minimum.

9.3 *Electrical Integrity*—Parts or coupons shall be subject to 20 cycles of the cyclic temperature-humidity test and then to the requirements of 8.2.5.1 and 8.2.5.2.

9.4 *Adhesion*—The coatings shall not peel or separate from the base material when subjected to the following tests.

9.4.1 *Tape Test*:

9.4.1.1 Apply a piece of pressure sensitive filament tape, approximately 25 mm wide and 75 mm long, onto the coated surface, pressing it firmly into place. Remove the tape, within 5 minutes, with a continuous, smooth and rapid pull at an angle of approximately 90°.

9.4.2 The filament tape shall be 25 ± 1 mm wide semitransparent pressure-sensitive tape with an adhesion strength of 44.6± 2.8 g/mm width when tested in accordance with Test Method D 3330/D 3330M. The adhesion shall not change more than ± 6.5 % of its mean value within 12 months.

9.4.2.1 *Pass/Fail Criteria*—Removal of any metal coating shall constitute test failure.

9.4.3 *Adhesion-Cross Hatch*—A series of six parallel cuts approximately 25 mm long and 3 mm apart are made through the coating by means of a sharp knife. Six similar cuts then are superimposed perpendicular to the original. All cuts must penetrate to the base material.

9.4.3.1 *Procedure*—Press a strip of pressure-sensitive filament tape approximately 25 mm wide and 75 mm long onto the

area formed by the cuts in the coating. Gently rub the tape into place and then remove the tape at an angle of 90° to the coated surface with a rapid pull. Examine the part and the tape for any coating removal.

9.4.3.2 *Pass/Fall Criteria*—Removal of more than 20 % (estimated) metal removal in any 3 of the 25 squares shall constitute test failure.

9.5 *Thermal Shock Resistance*—The thermal shock resistance of the coating system shall be evaluated by subjecting coated test coupons to a thermal shock test. A second set of test coupons shall be subjected to the cross hatch adhesion test (see 9.4.3).

9.5.1 *Pass/Fail Criteria*—Coupons subjected to the thermal shock test shall be stabilized for 30 minutes at room temperature and then examined at 10X magnification. Any evidence of chips, cracks, or delaminations shall constitute test failure. Coupons subjected to the cross hatch adhesion test shall be examined visually for coating removal. More than 50 % coating removal in any 3 of the 25 squares shall constitute test failure.

9.6 *Thermal Cycling Test*—Test specimens shall be subjected to Test Method B 553, service condition 2 for 3 cycles.

9.7 *Number of Samples*—The number of samples tested for each test shall be selected from the sampling plans of Test Method B 602.

9.8 *Shielding Effectiveness*—Parts or coupons shall meet the shielding effectiveness requirements shown in Table 1 after being subjected to 20 cycles of the cyclic temperature-humidity test when tested to Test Method D 4935.

10. Surface Preparation Recommendations

10.1 *Preparation of Metal Surfaces*—The following practices describe preparation methods that have been determined to be adequate: B 183, B 242, B 252, B 253, B 320, B 322.

10.2 *Preparation of Polymeric Surfaces*—Practice B 727 describes a preparation method that has been determined to be adequate.

11. Platable Polymeric Materials

11.1 Plating grades of the following polymeric types can be plated to this specification:

11.1.1 Polycarbonate;
11.1.2 Modified Polyphenylene Oxide;
11.1.3 Acetal;
11.1.4 Polysulfone;
11.1.5 Acrylonitrile-Butadiene-Styrene;
11.1.6 Polyphenolene ether;
11.1.7 Polystyrene;
11.1.8 Nylon;
11.1.9 Polyester; and
11.1.10 Styrene-Malic-Anhydride.