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Standard Guide for Selection of Porosity Tests for Electrodeposits and Related Metallic Coatings[1]

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1. Scope

1.1 This guide describes some of the available standard methods for the detection, identification, and measurement of porosity in electrodeposited and related metallic coatings and provides some laboratory-type evaluations and acceptances. Some applications of the test methods are tabulated in Table 1 and Table 2.

1.2 This guide does not apply to coatings that are produced by thermal spraying, ion bombardment, sputtering, and other similar techniques where the coatings are applied in the form of discrete particles impacting on the substrate.

1.3 This guide does not apply to beneficial or controlled porosity, such as that present in microdiscontinuous chromium coatings.

1.4 Porosity test results occur as chemical reaction end products. Some occur in situ, others on paper, or in a gel coating. Observations are made that are consistent with the test method, the items being tested, and the requirements of the purchaser. These may be visual inspection (unaided eye) or by 10× magnification (microscope). Other methods may involve enlarged photographs or photomicrographs.

1.5 The test methods are only summarized. The individual standards must be referred to for the instructions on how to perform the tests.

1.6 The values stated in SI units are to be regarded as standard. The values given in parentheses are for information only.

1.7 *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 246 Specification for Tinned Hard-Drawn and Medium-Hard-Drawn Copper Wire for Electrical Purposes[2]

B 276 Test Method for Apparent Porosity in Cemented Carbides[3]

B 374 Terminology Relating to Electroplating[3]

B 537 Practice for Rating of Electroplated Panels Subjected to Atmospheric Exposure[3]

B 542 Terminology Relating to Electrical Contacts and Their Use[4]

B 545 Specification for Electrodeposited Coatings of Tin[3]

B 605 Specification for Electrodeposited Coatings of Tin-Nickel Alloy[3]

B 650 Specification for Electrodeposited Engineering Chromium Coatings of Ferrous Substrates[3]

B 689 Specification for Electroplated Engineering Nickel Coatings[3]

B 733 Specification for Autocatalytic (Electroless) Nickel-Phosphorous Coatings on Metals[3]

B 734 Specification for Electrodeposited Copper for Engineering Uses[3]

B 735 Test Method for Porosity in Gold Coatings on Metal Substrates by Nitric Acid Vapor[4]

B 741 Test Method for Porosity in Gold Coatings on Metal Substrates by Paper Electrography[4]

B 798 Test Method for Porosity in Gold or Palladium Coatings on Metal Substrates by Gel-Bulk Electrography[4]

B 799 Test Method for Porosity in Gold and Palladium Coatings by Sulfurous Acid/Sulfur-Dioxide Vapor[4]

B 809 Test Method for Porosity in Metallic Coatings by Humid Sulfur Vapor ("Flowers-of-Sulfur")[3]

3. Terminology

3.1 *Definitions*—Many terms used in this guide are defined in Terminology B 374 or B 542.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *porosity*—for the purpose of this guide, porosity in a coating is defined as any hole, crack, or other defect that exposes the underlying metal to the environment.

3.2.2 *underplate*—a metallic coating layer between the basis metal and the topmost metallic coating. The thickness of

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[1] This guide is under the jurisdiction of ASTM Committee B08 on Metallic and Inorganic Coatings and is the direct responsibility of Subcommittee B08.10 on Test Methods.

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[2] *Annual Book of ASTM Standards*, Vol 02.03.

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

[4] *Annual Book of ASTM Standards*, Vol 02.04.

TABLE 1 Applications of Standard Porosity Tests to Metallic Coatings (Section 6)

Substrate Metal[A]	Gold	Silver	Nickel	Tin-Nickel	Tin	Tin-Lead	Copper	Palladium	Chromium
Copper and Copper Alloys	6.1[B], 6.2, 6.4, 6.5	6.3A	6.4	6.4	6.4	6.4	...	6.2, 6.3A, 6.4, 6.5	...
Nickel	6.1[B], 6.2, 6.5	6.3A	...	...	...	...	...	6.2, 6.3A, 6.5	...
Iron or Steel	6.6	...	6.6	6.3B, 6.6	6.3B, 6.6	6.3B, 6.6	6.6	...	6.6
Silver	6.4	...	6.4	6.4	6.4	6.4	...	6.4	...

[A] The substrate may be the basis metal, an underplate, or both (see Note 1).
[B] Thickness restrictions may apply.

TABLE 2 Applications of Tests for Gross Defects and Mechanical Damage (Section 7)

Substrate Metal[A]	Gold	Nickel	Tin-Nickel	Tin	Tin-Lead	Palladium	Silver
Copper and Copper Alloys	7.3, 7.5	7.3, 7.4	7.3	7.3	7.3	7.3, 7.5	7.5
Nickel	7.5	...	...	...	...	7.5	7.5
Iron or Steel	7.1	7.1	7.1	7.1	7.1	7.1	...
Aluminum	...	7.2	...	...	...	...	...

[A] The substrate may be the basis metal, an underplate, or both (see Note 1).

an underplating is usually greater than 1 µm, in contrast to a strike or flash, which are usually thinner.

4. Significance and Use

4.1 Porosity tests indicate the completeness of protection or coverage offered by the coating. When a given coating is known to be protective when properly deposited, the porosity serves as a measure of the control of the process. The effects of substrate finish and preparation, plating bath, coating process, and handling, may all affect the degree of imperfection that is measured.

NOTE 1—The substrate exposed by the pores may be the basis metal, an underplate, or both.

4.2 The tests in this guide involve corrosion reactions in which the products delineate pores in coatings. Since the chemistry and properties of these products may not resemble those found in service environments, these tests are not recommended for prediction of product performance unless correlation is first established with service experience.

5. Applications

5.1 From the viewpoint of both porosity testing and functional significance, it is useful to divide porosity into two broad categories, namely intrinsic porosity and gross defects.[5,6]

5.1.1 *Intrinsic* or *normal* porosity is due primarily to small deviations from ideal plating and surface preparation conditions. As such, it will be present to some degree in all commercial thin platings and will generally follow an inverse relationship with thickness. In addition, scanning electron microscope (SEM) studies have shown that the diameter of such pores at the plating surface is of the order of micrometers, so that only small areas of underlying metal are exposed to the environment.

5.1.2 *Gross defects*, on the other hand, would result in comparatively large areas of exposed basis metal or underplating. Examples of such defects are mechanical damage to the coating through mishandling or wear. Gross defects can also be found in undamaged coatings in the form of networks of microcracks and as large as-plated pores—with diameters an order of magnitude (or more) greater than intrinsic porosity. Such gross defects indicate such serious deviations from acceptable coating practice as dirty substrates and contaminated or out-of-balance baths.

5.2 Intrinsic porosity and most types of gross defects are too small to be seen except at magnifications so high that a realistic assessment of the overall coating surface in the functional areas of the part cannot be made. Instead, the presence and severity of the porosity is normally determined by some type of pore-corrosion test that will magnify the pore sites by producing visible reaction products in and around the pores or cracks. Tests for gross defects (Section 7), and especially for mechanical damage and wear, are designed to be less severe. Such tests, however, may not detect a sizeable portion of the smaller (intrinsic) pores in a coating. On the other hand, standard tests for intrinsic porosity (Section 6) will easily reveal the presence of gross defects as well.

5.3 Porosity tests are generally destructive in nature and are designed to assess the quality of the coating process in conjunction with the substrate. Therefore, separate test specimens are not ordinarily allowed.

5.4 In the tests summarized in this guide, chemicals react with the exposed substrate through the pore or channel to form a product that is either directly observable or that is made observable by subsequent chemical development.

5.5 Porosity tests differ from corrosion and aging tests. A good porosity test process must clean, depolarize, and activate the substrate metal exposed by the pore, and attack it sufficiently to cause reaction products to fill the pore to the surface of the coating. The corrosive reagent ideally does not react with the coating. Reaction time is limited, particularly with thin coatings, since the corrosive will attack the substrate in all directions and, in so doing, undermine the coatings so that false observations may be made. When the corrosion product is soluble in the reagent, a precipitating indicator is used to form the reaction product.

5.6 The substrate exposed by the pores may be the basis

[5] Baker, R. G., Holden, C. A., and Mendizza, A., Proceedings of the American Electroplaters Society, Vol 50, 1963, p. 61.

[6] Krumbein, S. J., "The ASTM Approach to Porosity Testing," Proc. 1991 International Technical Conf. of the American Electroplaters and Surface Finishers Soc., (SUR/FIN '91), Toronto, 1991, pp. 527–536.