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Standard Guide for Measuring Thickness of Metallic and Inorganic Coatings[1]

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1. Scope

1.1 This guide covers the methods for measuring the thickness of many metallic and inorganic coatings including electrodeposited, mechanically deposited, vacuum deposited, anodic oxide, and chemical conversion coatings.

1.2 This guide is limited to tests considered in ASTM standards and does not cover certain tests that are employed for special applications.

1.3 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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

B244 Test Method for Measurement of Thickness of Anodic Coatings on Aluminum and of Other Nonconductive Coatings on Nonmagnetic Basis Metals with Eddy-Current Instruments

B487 Test Method for Measurement of Metal and Oxide Coating Thickness by Microscopical Examination of Cross Section

B499 Test Method for Measurement of Coating Thicknesses by the Magnetic Method: Nonmagnetic Coatings on Magnetic Basis Metals

B504 Test Method for Measurement of Thickness of Metallic Coatings by the Coulometric Method

B530 Test Method for Measurement of Coating Thicknesses by the Magnetic Method: Electrodeposited Nickel Coatings on Magnetic and Nonmagnetic Substrates

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

B588 Test Method for Measurement of Thickness of Transparent or Opaque Coatings by Double-Beam Interference Microscope Technique

B681 Test Method for Measurement of Thickness of Anodic Coatings on Aluminum and of Other Transparent Coatings on Opaque Surfaces Using the Light-Section Microscope (Discontinued 2001) (Withdrawn 2001)[3]

B767 Guide for Determining Mass Per Unit Area of Electrodeposited and Related Coatings by Gravimetric and Other Chemical Analysis Procedures

2.2 *ISO Standards:*[4]

1463 Metal and Oxide Coatings—Measurement of Thickness by Microscopic Examination of Cross Sections

2128 Surface Treatment of Metals—Anodization (Anodic Oxidation) of Aluminum and Its Alloys—Measurement of the Thickness of Oxide Coatings—Nondestructive Measurement by Light Section Microscope

2176 Petroleum Products Lubricating Grease Determination of Dropping Point

2177 Metallic Coatings—Measurement of Coating Thickness—Coulometric Method by Anodic Solution

2178 Non-Magnetic Metallic and Vitreous or Porcelain Enamel Coatings on Magnetic Basis Metals, Measurement of Coating Thickness, Magnetic Method

2360 Non-Conductive Coatings on Non-Magnetic Basis Metals—Measurement of Coating Thickness—Eddy Current Method

2361 Electrodeposited Nickel Coatings on Magnetic and Non-Magnetic Substrates—Measurement of Coating Thickness—Magnetic Method

3497 Metallic Coatings—Measurement of Coating Thickness—X-Ray Spectrometric Methods

3543 Metallic and Non-Metallic Coatings—Measurement of Thickness—Beta Backscatter Method

[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] 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.

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

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

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3. Significance and Use

3.1 Most coating specifications specify the thickness of the coating because coating thickness is often an important factor in the performance of the coating in service.

3.2 The methods included in this guide are suitable for acceptance testing and are to be found in ASTM standards.

3.3 Each method has its own limitations with respect to the kind of coating and its thickness.

4. Reliability of Methods

4.1 All methods covered by this guide are sufficiently reliable to be used for acceptance testing of many electroplated and other coatings. That is, each method is capable of yielding measurements with an uncertainty of less than 10 % of the coating thickness over a significant range of coating thicknesses when used by properly instructed personnel.

5. Nondestructive Methods

5.1 *Magnetic Methods*—These methods employ instruments that measure the magnetic attraction between a magnet and the coating or the substrate or both, or that measure the reluctance of a magnetic flux path passing through the coating and the substrate. These methods, in practice, are limited to nonmagnetic coatings on carbon steel (Test Method B499 and ISO 2178) and to electrodeposited nickel coatings on carbon steel or on nonmagnetic substrates (Test Method B530 and ISO 2361) and to nonmagnetic autocatalytically deposited nickel-phosphorus alloys on carbon steel (Test Method B499 and ISO 2176). Coating thickness gages of this type are available commercially.

5.2 *Eddy-Current Method*—This method employs an instrument that generates a high-frequency current in a probe, inducing eddy currents near the surface of the test specimen. The magnitude of the eddy currents is a function of the relative conductivities of the coating and substrate materials and the coating thickness. Because variation in the electroplating process can change the electrical properties of the coating and, hence, instrument response for a given thickness, the use of eddy-current instruments is usually limited to the measurement of nonconductive coatings on nonmagnetic basis metals (Test Method B244 and ISO 2360). These instruments are, however, also suitable for the thickness measurement of high-conductivity metal (for example, copper and silver) coatings on nonconductive substrates. Coating thickness gages of this type are available commercially.

5.3 *X-Ray Fluorescence Methods:*

5.3.1 These methods cover the use of emission and absorption X-ray spectrometry for determining the thickness of metallic coatings up to about 15 µm. The upper limit may be significantly above or below 15 µm depending on the coating material and on the equipment used. When exposed to X rays, the intensity of the secondary radiation emitted by the coating or by the substrate followed by attenuation by the coating is measured. The intensity of the secondary radiation is a function of the coating thickness.

5.3.2 In multiple coatings the X-ray method is generally applicable to the final metal coating.

5.3.3 Suitable equipment is available commercially (Test Method B568 and ISO 3497).

5.4 *Beta Backscatter Method:*

5.4.1 The beta backscatter method employs radioisotopes that emit beta radiation and a detector that measures the intensity of the beta radiation backscattered by the test specimen. Part of the beta radiation entering the material collides with atoms of the material and is scattered back towards the source. The intensity of the backscattered radiation is a function, among others, of the coating thickness. A measurement is possible if the atomic number of the coating material is sufficiently different from that of its substrate and if the beta radiation is of suitable energy and intensity. The method can be used for measuring both thin and thick coatings, the maximum thickness being a function of the atomic number of the coating. In practice, high atomic number coatings, such as gold, can be measured up to 50 µm, while low atomic number coatings, such as copper or nickel, can be measured up to about 200 µm.

5.4.2 Coating thickness gages of this type are available commercially (Test Method B567 and ISO 3543).

6. Semidestructive Methods

6.1 *Coulometric Method:*

6.1.1 Coating thickness may be determined by measuring the quantity of electricity consumed in dissolving the coating from an accurately defined area when the article is made anodic in a suitable electrolyte under suitable conditions. The change in potential occurring when the substrate is exposed indicates the end point of the dissolution. The method is applicable to many coating-substrate combinations (Test Method B504 and ISO 2177).

6.1.2 Coating thickness instruments employing this method are available commercially.

6.2 *Double-Beam Interference Microscope Method*—A step is formed between the coating surface and the substrate surface by dissolving a small area of coating. The height of this step is measured with a double-beam interference microscope. The method is applicable to thin coatings such as usually used for decorative chromium. It can be used to measure transparent oxide coatings without the need of forming a step (Test Method B588).

7. Destructive Methods

7.1 *Microscopical Method*—In the microscopical method the thickness is measured in a magnified image of a cross section of the coating (Test Method B487 and ISO 1463).

7.2 *Gravimetric Method (Strip and Weigh):*

7.2.1 The coating mass is determined by weighing the sample before and after dissolving the coating without attack of the substrate or by weighing the coating after dissolving the substrate without attack of the coating.

7.2.2 The coating thickness is given by the equation:

$$t = \frac{m \times 10}{d \times A} \quad (1)$$

where:

TABLE 1 Applicability of Coating Thickness Measuring Methods

NOTE 1—B = Beta backscatter; C = Coulometric; E = Eddy current; and M = Magnetic.

Substrates	Coatings														
	Copper	Nickel	Chro-mium	Auto-catalytic Nickel	Zinc	Cad-mium	Gold	Palla-dium	Rhod-ium	Silver	Tin	Lead	Tin-Lead Alloys	Non-metals	Vitreous and Por-celain Enamels
Magnetic steel (including corrosion-resisting steel)	CM	CM[A]	CM	C[B] M[A]	CM	BCM	BM	BM	BM	BCM	BCM	BCM	B[C] C[C] M	BM	M
Nonmagnetic stainless steels	CE[D]	CM[A]	C	C[B]	C	BC	B	B	B	BCE[D]	BC	BC	B[C] C[C]	BE	E
Copper and alloys	C only on brass and Cu-Be	CM[A]	C	C[B]	C	BC	B	B	B	BC	BC	BC	B[C] C[C]	BE	E
Zinc and alloys	C	M[A]	...	...	...	B	B	B	B	B	B	B	B[C]	BE	...
Aluminum and alloys	BC	BCM[A]	BC	BC[B] E[A,B]	BC	BC	B	B	B	BC	BC	BC	B[C] C[C]	E	E
Magnesium and alloys	B	BM[A]	B	B	B	B	B	B	B	B	B	B	B[C]	E	...
Nickel	C	...	C	...	C	BC	B	B	B	BC	BC	BC	B[C] C[C]	BE	...
Silver	B	BM[A]	B	B	B	...	B	...	...	...	...	BC	B[C]	BE	E
Glass Sealing Nickel-cobalt-iron alloys UNS No. K94610	M	CM[A]	M	C[B] M[A]	M	BM	BM	BM	BM	BM	BM	BCM	B[A] C[C] M	BM	...
Nonmetals	BCE[D]	BCM[A]	BC	BC[B]	BC	BC	B	B	B	BC	BC	BC	B[C] C[C]	...	...
Titanium	B	BM[A]	BC[B]	BE[A,B]	B	B	B	B	B	B	B	B	B[C]	BE	...

[A] Method is sensitive to permeability variations of the coating.
[B] Method is sensitive to variations in the phosphorus content of the coating.
[C] Method is sensitive to alloy composition.
[D] Method is sensitive to conductivity variations of the coating.

t = thickness, μm,
d = density of coating material, g/cm^3,
m = mass of coating, mg, and
A = area covered by coating, cm^2.

7.2.3 Procedures for applying this method to many different coatings are given in Guide B767.

7.2.4 A variation of this method is to weigh the item before and after electroplating or, if the current efficiency is 100 %, to measure the coulombs passed during the electroplating to determine the coating weight.

8. Other Methods

8.1 Profilometry and multiple-beam interferometry offer reliable methods of measuring coating thickness provided a step can be formed by removing a portion of the coating.

8.2 The light section microscope is used for measuring the thickness of non-opaque coatings on relatively smooth substrates (Test Method B681 and ISO 2128).

9. Summary of Applicability of Coating Thickness Measuring Methods

9.1 The applicability and limitations of coating gages and other methods of measuring coating thickness are set forth in the pertinent ASTM and ISO standards, publications on electroplating and related finishing technology, and manufacturers' instructions for the use of coating thickness gages. The X-ray, gravimetric, microscopical, and interference microscopical methods are applicable to almost all combinations of substrate and coatings. Table 1 indicates the substrate and coating combinations to which the beta backscatter, coulometric, eddy-current, and magnetic methods have been applied.

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