Designation: D2442 – 75 (Reapproved 2020)

Standard Specification for Alumina Ceramics for Electrical and Electronic Applications[1]

This standard is issued under the fixed designation D2442; 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 the requirements for fabricated alumina parts suitable for electronic and electrical applications and ceramic-to-metal seals as used in electron devices. This specification specifies limits and methods of test for electrical, mechanical, thermal, and general properties of the bodies used for these fabricated parts, regardless of part geometry.

1.2 The values stated in SI units are to be regarded as standard. The values given in parentheses after SI units are provided for information only and are not considered standard.

1.3 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C20 Test Methods for Apparent Porosity, Water Absorption, Apparent Specific Gravity, and Bulk Density of Burned Refractory Brick and Shapes by Boiling Water

C108 Symbols for Heat Transmission

C242 Terminology of Ceramic Whitewares and Related Products

C408 Test Method for Thermal Conductivity of Whiteware Ceramics

C573 Methods for Chemical Analysis of Fireclay and High-Alumina Refractories (Withdrawn 1995)[3]

C623 Test Method for Young's Modulus, Shear Modulus, and Poisson's Ratio for Glass and Glass-Ceramics by Resonance

D116 Test Methods for Vitrified Ceramic Materials for Electrical Applications

D149 Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies

D150 Test Methods for AC Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulation

D257 Test Methods for DC Resistance or Conductance of Insulating Materials

D618 Practice for Conditioning Plastics for Testing

D1711 Terminology Relating to Electrical Insulation

D1829 Test Method for Electrical Resistance of Ceramic Materials at Elevated Temperatures (Withdrawn 2001)[3]

D2149 Test Method for Permittivity (Dielectric Constant) And Dissipation Factor Of Solid Dielectrics At Frequencies To 10 MHz And Temperatures To 500°C

D2520 Test Methods for Complex Permittivity (Dielectric Constant) of Solid Electrical Insulating Materials at Microwave Frequencies and Temperatures to 1650°C

E6 Terminology Relating to Methods of Mechanical Testing

E12 Terminology Relating to Density and Specific Gravity of Solids, Liquids, and Gases (Withdrawn 1996)[3]

E122 Practice for Calculating Sample Size to Estimate, With Specified Precision, the Average for a Characteristic of a Lot or Process

E165/E165M Practice for Liquid Penetrant Testing for General Industry

E228 Test Method for Linear Thermal Expansion of Solid Materials With a Push-Rod Dilatometer

F19 Test Method for Tension and Vacuum Testing Metallized Ceramic Seals

F77 Test Method for Apparent Density of Ceramics for Electron Device and Semiconductor Application (Withdrawn 2001)[3]

F109 Terminology Relating to Surface Imperfections on Ceramics

F134 Test Methods for Determining Hermeticity of Electron Devices with a Helium Mass Spectrometer Leak Detector (Withdrawn 1996)[3]

F417 Test Method for Flexural Strength (Modulus of Rupture) of Electronic-Grade Ceramics (Withdrawn 2001)[3]

[1] This specification is under the jurisdiction of Committee C21 on Electrical and Electronic Insulating Materials.

Current edition approved Nov. 1, 2020. Published December 2020. Originally approved in 1965. Last previous edition approved in 2016 as D2442 – 75 (2016). DOI: 10.1520/D2442-75R20.

[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.

2.2 *Other Standards:*

MIL-STD-105 Sampling Procedures and Tables for Inspection by Attributes[4]

MIL-STD-883 Test Methods and Procedures for Microelectronics[5]

ANSI B46.1 Surface Texture[6]

3. Terminology

3.1 *Definitions:*

3.1.1 The applicable definitions of terms in the following documents shall apply to this specification: Symbols C108, and Terminology C242, D1711, E6, E12, and F109.

4. Classification

4.1 Ceramics covered by this specification shall be classified by alumina content as follows:

Type	Alumina Content Weight %, min
I	82
II	93
III	97
IV	99

5. Basis of Purchase

5.1 Purchase orders for ceramic parts furnished to this specification shall include the following information:

5.1.1 Type designation (see 3.1),

5.1.2 Surface finish and allowable defect limits (if required) (Terminology F109, ANSI B46.1, and Appendix X1),

5.1.3 Part drawing with dimensional tolerances (Appendix X1),

5.1.4 Specific tests (if required),

5.1.5 Certification (if required), and

5.1.6 Packing and marking.

6. Requirements

6.1 This material shall conform to the electrical, mechanical, thermal, and general property requirements specified in Tables 1-4.

6.2 Dimensional and surface finish requirements of the parts shall be as agreed between the supplier and the purchaser; however, guidance for establishing such an agreement is provided in Appendix X1.

6.3 *Visual Requirements:*

6.3.1 Parts shall be uniform in color and texture. Cracks, blisters, holes, porous areas, inclusions, and adherent foreign particles shall not be permitted. The limits of surface imperfections such as pits, pocks, chips (open or closed), surface marks, fins, ridges, and flow lines shall be set by mutual agreement between the supplier and the purchaser. Limiting dimensions for these defects, when required for clarification, will be listed in the parts drawing or purchase description. For definitions of the surface imperfections enumerated above, see Terminology F109.

6.3.2 For hermetic seal applications at least ¾ of the width of the seal surface shall remain intact at the location of any defect.

6.3.3 On other surfaces the limits for defects are such that the dimensional tolerances of the part are not affected at the location of the defect.

TABLE 1 Electrical Requirements

Property	Type I	Type II	Type III	Type IV
Dielectric Constant, max 25 °C:				
at 1 MHz	8.8	9.6	9.8	10.1
at 10 GHz	8.7	9.6	9.8	10.1
Dissipation factor, max 25 °C:				
at 1 MHz	0.002	0.001	0.0005	0.0002
at 10 GHz	0.002	0.001	0.0005	0.0002
Volume Resistivity, min Ω·cm:				
at 25 °C	10^{14}	10^{14}	10^{14}	10^{14}
at 300 °C	1×10^{10}	1×10^{10}	1×10^{10}	7×10^{10}
at 500 °C	4×10^{7}	2×10^{7}	8×10^{7}	1×10^{8}
at 700 °C	4×10^{6}	2×10^{6}	6×10^{6}	1×10^{7}
at 900 °C	4×10^{5}	2×10^{5}	8×10^{5}	1×10^{6}
Dielectric Strength, 3.175 mm, min Ω·cm:	9.85 (250 V/mil)	9.85 (250 V/mil)	9.85 (250 V/mil)	9.85 (250 V/mil)

TABLE 2 Mechanical Requirements

Property	Type I	Type II	Type III	Type IV
Flexural strength, min avg,[A] MPa (psi)	240 (35 000)	275 (40 000)	275 (40 000)	275 (40 000)
Modulus of elasticity, min, GPa (psi)	215 (31×10^{6})	275 (40×10^{6})	310 (45×10^{6})	345 (50×10^{6})
Poisson's ratio, average	0.20–0.25	0.20–0.25	0.20–0.25	0.20–0.25

[A] Maximum permissible coefficient of variation is 10 %.

7. Test Specimens

7.1 The preferred specimens for test are, where possible, the actual part. When necessary, however, specific test specimens shall be prepared from the same batch of material and by the same processes as those employed in fabricating the ceramic part insofar as possible.

8. Specimen Preparation

8.1 The specimens for tests described in 9.1 – 9.3 shall be preconditioned in accordance with Procedure A of Test Methods D618.

9. Test Methods

9.1 *Dielectric Constant and Dissipation Factor*—Determine in accordance with Test Methods D150. Determine values at higher frequencies in accordance with Test Methods D2520.[7] Determine values at higher temperatures in accordance with Test Method D2149.

[4] Available from U.S. Government Printing Office, Superintendent of Documents, 732 N. Capitol St., NW, Washington, DC 20401-0001, http://www.access.gpo.gov.

[5] Available from DLA Document Services, Building 4/D, 700 Robbins Ave., Philadelphia, PA 19111-5094, http://quicksearch.dla.mil.

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

[7] For another suitable method see von Hippel, A. (ed.), *Dielectric Materials and Applications*, John Wiley and Sons, Inc., New York, NY, 1954.

TABLE 3 Thermal Requirements

Property	Type I		Type II		Type III		Type IV	
	min	max	min	max	min	max	min	max
Mean coefficient of linear thermal expansion, μ m/m · °C:								
25–200 °C	5.4	6.2	5.2	6.7	5.2	6.5	5.5	6.7
25–500 °C	6.5	7.0	6.6	7.4	6.7	7.5	6.8	7.6
25–800 °C	7.0	7.7	7.3	8.1	7.4	8.1	7.3	8.1
25–1000°C	7.4	8.2	7.5	8.3	7.6	8.3	7.5	8.4
Thermal conductivity, cal/s·cm·°C:								
at 100 °C	0.023	0.049	0.031	0.077	0.048	0.073	0.052	0.090
at 400 °C	0.015	0.022	0.014	0.036	0.022	0.033	0.023	0.047
at 800 °C	0.009	0.018	0.009	0.021	0.014	0.021	0.014	0.025
Thermal shock resistance	pass		pass		pass		pass	
Maximal deformation at 1500 °C	...		...		0.51 mm (0.02 in.)		0.51 mm (0.02 in.)	

TABLE 4 General Requirements[A]

Property	Type			
	I	II	III	IV
Density, apparent min,[B] g/cm^3	3.37	3.57	3.72	3.78
Composition, min, weight %	82	93	97	99
Gas impermeability	gas tight	gas tight	gas tight	gas tight
Liquid impermeability	pass	pass	pass	pass
Metallizability[A]	[C]	[C]	[C]	[C]

[A] Vendors shall, upon request, provide information on these properties as well as a visual standard of a typical microstructure of their specific ceramic body depicting its grain size and pore volume. Changes in microstructure of the ceramic are not acceptable as they can affect the behavior of the ceramic toward a metallizing process.

[B] The apparent density of a ceramic body is a function of the amount and the density of the primary Al_2O_3 phase and the secondary phase plus the amount of pores inherent to that body. The acceptable density limits for a specific alumina body must be consistent with the composition and the pore volume of the ceramic supplied by supplier and shall be agreed upon between the purchaser and the supplier. Variation in the apparent density of a specific ceramic body shall be within ±1 % of the nominal value.

[C] Generally, very high alumina content results in increased difficulty of metallizing; however, variations in metallizing compositions and techniques can produce excellent seals in all four types of alumina ceramics. Because of a wide variation in materials and techniques, no specific test is recommended. A referee test for seal strength is Test Method F19.

9.2 *Volume Resistivity*—Determine in accordance with Test Methods D257. For elevated temperature measurements use Procedure A of Test Method D1829.

9.3 *Dielectric Strength*—Run this test under oil in accordance with 6.1.1 of Test Methods D149, with a rise rate of 1000 V⁄s on a 3.175 mm (0.125-in.) thick test specimen.

9.4 *Flexural Strength*—Determine in accordance with Test Method F417 or D116. Somewhat lower values will result if Test Method D116 are used. The test method to be used shall be agreed upon between the supplier and the purchaser.

9.5 *Modulus of Elasticity and Poisson's Ratio*—Determine in accordance with Test Method C623.

9.6 *Thermal Expansion*—Determine in accordance with Test Method E228.

9.7 *Thermal Conductivity*—Determine in accordance with Test Method C408. For temperatures in excess of 149 °C (300 °F), use a suitable method.[8]

[8] For a suitable method see Francl, J., and Kingery, W. D., "An Apparatus for Determining Conductivity by a Comparative Method," *Journal of the American Ceramic Society*, JACTA Vol 37, 1954, p. 80.

9.8 *Thermal Shock Resistance*—This test is to be agreed upon between supplier and purchaser. It is suggested that the cold end of the cycle be ice water at 0 °C. Methods of heating and conditions at elevated temperatures shall be negotiated. The transfer from one temperature extreme to another shall be immediate.

9.9 *Temperature Deformation*—Determine deformation at 1500 °C in accordance with Appendix X2.

9.10 *Apparent Density*—Determine in accordance with Test Method F77. For large ceramic parts not covered by this test method, determine in accordance with Test Methods C20.

9.11 *Compositional Analysis*—Use either quantitative emission spectrographic analysis of the fired ceramic with alumina content determined by difference or Test Methods C573 after assuming that all determined metallic and reactive elements originally are present as their highest form of oxide.

9.12 *Gas Impermeability*—When air fired at 900 °C for 30 min and handled with tweezers only, then tested on a helium mass spectrometer leak detector capable of detecting a leak of 10^{-9} atm·cm^3/s, the ceramic is considered impermeable if a specimen 0.254 mm (0.010 in.) thick shows no indication of helium leakage when an area of 322.6 mm^2 (0.5 in.^{2}) is tested for 15 s at room temperature (Method 1014, Seal, of MIL-STD-883 and Test Methods F134).

9.13 *Liquid Impermeability*—Determine in accordance with Test Methods D116.

9.14 *Surface Imperfections*—Examine visually for surface imperfections with or without the aid of a dye penetrant as in Practice E165/E165M. Agreement by purchaser and supplier regarding specific techniques is strongly recommended.

9.15 *Surface Finish*—If surface finish is specified, it shall be determined by any appropriate method agreed upon by purchaser and supplier.

10. Inspection

10.1 When agreed upon between the manufacturer and the purchaser, the purchaser may inspect the ceramic parts and verify the test results at the manufacturer's facility. Otherwise the purchaser shall inspect and test the ceramic parts within one month of the date of receipt by the purchaser or at such other times as may be agreed upon between the purchaser and the manufacturer.