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Standard Classification for Fiber Reinforced Silicon Carbide-Silicon Carbide (SiC-SiC) Composite Structures[1]

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1. Scope

1.1 This classification covers silicon carbide-silicon carbide (SiC-SiC) composite structures (flat plates, rectangular bars, round rods, and tubes) manufactured for structural components. The SiC-SiC composites consist of continuous silicon carbide fibers in a silicon carbide matrix produced by four different matrix densification methods.

1.2 The classification system provides a means of identifying and organizing different SiC-SiC composites, based on the fiber type, architecture class, matrix densification, physical properties, and mechanical properties. The system provides a top-level identification system for grouping different types of SiC-SiC composites into different classes and provides a means of identifying the general structure and properties of a given SiC-SiC composite. It is meant to assist the ceramics community in developing, selecting, and using SiC-SiC composites with the appropriate composition, construction, and properties for a specific application.

1.3 The classification system produces a classification code for a given SiC-SiC composite, which shows the type of fiber, reinforcement architecture, matrix type, fiber volume fraction, density, porosity, and tensile strength and modulus (room temperature).

1.3.1 For example, Composites Classification Code, *SC2-A2C-4D10-33*—a SiC-SiC composite material/component (*SC2*) with a 95 %+ polymer precursor (*A*) based silicon carbide fiber in a 2D (*2*) fiber architecture with a CVI matrix (*C*), a fiber volume fraction of 45 % (*4* = 40 to 45 %), a bulk density of 2.3 g/cc (*D* = 2.0 to 2.5 g/cc), an apparent porosity of 12 % (*10* = 10 to 15 %), an average ultimate tensile strength of 350 MPa (*3* = 300 to 399 MPa), and an average tensile modulus of 380 GPa (*3* = 300 to 399 GPa).

1.4 This classification system is a top level identification tool which uses a limited number of composite properties for high level classification. It is not meant to be a complete, detailed material specification, because it does not cover the full range of composition, architecture, physical, mechanical, fabrication, and durability requirements commonly defined in a full design specification. Guide C1793 provides extensive and detailed direction and guidance in preparing a complete material specification for a given SiC-SiC composite component.

1.5 *Units*—The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.6 *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]

C242 Terminology of Ceramic Whitewares and Related Products

C559 Test Method for Bulk Density by Physical Measurements of Manufactured Carbon and Graphite Articles

C1039 Test Methods for Apparent Porosity, Apparent Specific Gravity, and Bulk Density of Graphite Electrodes

C1145 Terminology of Advanced Ceramics

C1198 Test Method for Dynamic Young's Modulus, Shear Modulus, and Poisson's Ratio for Advanced Ceramics by Sonic Resonance

C1259 Test Method for Dynamic Young's Modulus, Shear Modulus, and Poisson's Ratio for Advanced Ceramics by Impulse Excitation of Vibration

C1275 Test Method for Monotonic Tensile Behavior of Continuous Fiber-Reinforced Advanced Ceramics with Solid Rectangular Cross-Section Test Specimens at Ambient Temperature

C1773 Test Method for Monotonic Axial Tensile Behavior of Continuous Fiber-Reinforced Advanced Ceramic Tubular Test Specimens at Ambient Temperature

C1793 Guide for Development of Specifications for Fiber

[1] This classification is under the jurisdiction of ASTM Committee C28 on Advanced Ceramics and is the direct responsibility of Subcommittee C28.07 on Ceramic Matrix Composites.

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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.

Reinforced Silicon Carbide-Silicon Carbide Composite Structures for Nuclear Applications
D3878 Terminology for Composite Materials
D4850 Terminology Relating to Fabrics and Fabric Test Methods
D6507 Practice for Fiber Reinforcement Orientation Codes for Composite Materials
E6 Terminology Relating to Methods of Mechanical Testing
E111 Test Method for Young's Modulus, Tangent Modulus, and Chord Modulus
E1309 Guide for Identification of Fiber-Reinforced Polymer-Matrix Composite Materials in Databases (Withdrawn 2015)[3]

3. Terminology

3.1 *General Definitions*—Many of the terms in this classification are defined in the terminology standards for ceramic whitewares (C242), advanced ceramics (C1145), composite materials (D3878), fabrics and fabric test methods (D4850), and mechanical testing (E6).

3.1.1 *apparent porosity, n*—the volume fraction of all pores, voids, and channels within a solid mass that are interconnected with each other and communicate with the external surface, and thus are measurable by gas or liquid penetration. (Synonym – open porosity) **C242**

3.1.2 *braided fabric, n*—a woven structure produced by interlacing three or more ends of yarns in a manner such that the paths of the yarns are diagonal to the vertical axis of the fabric.

3.1.2.1 *Discussion*—Braided structures can have 2D or 3D architectures. **D4850**

3.1.3 *bulk density, n*—the mass of a unit volume of material including both permeable and impermeable voids. **C559**

3.1.4 *ceramic matrix composite, n*—a material consisting of two or more materials (insoluble in one another), in which the major, continuous component (matrix component) is a ceramic, while the secondary component(s) (reinforcing component) may be ceramic, glass-ceramic, glass, metal, or organic in nature. These components are combined on a macroscale to form a useful engineering material possessing certain properties or behavior not possessed by the individual constituents. **C1145**

3.1.5 *fabric, n—in textiles*, a planar structure consisting of yarns or fibers. **D4850**

3.1.6 *fiber, n*—a fibrous form of matter with an aspect ratio >10 and an effective diameter <1 mm. (Synonym – filament)

3.1.6.1 *Discussion*—A fiber/filament forms the basic element of fabrics and other textile structures. **D3878**

3.1.7 *fiber fraction (volume or weight), n*—the amount of fiber present in a composite, expressed either as a percent by weight or a percent by volume. **D3878**

3.1.8 *fiber preform, n*—a preshaped fibrous reinforcement, normally without matrix, but often containing a binder to facilitate manufacture, formed by distribution/weaving of fibers to the approximate contour and thickness of the finished part. **D3878**

3.1.9 *hybrid, n—for composite materials*, containing at least two distinct types of matrix or reinforcement. Each matrix or reinforcement type can be distinct because of its *(a)* physical or mechanical properties, or both, *(b)* material form, or *(c)* chemical composition. **D3878**

3.1.10 *knitted fabric, n*—a fiber structure produced by interlooping one or more ends of yarn or comparable material. **D4850**

3.1.11 *laminate, n*—any fiber- or fabric-reinforced composite consisting of laminae (plies) with one or more orientations with respect to some reference direction. **D3878**

3.1.12 *lay-up, n*—a process or fabrication involving the placement of successive layers of materials in specified sequence and orientation. **D6507, E1309**

3.1.13 *matrix, n*—the continuous constituent of a composite material, which surrounds or engulfs the embedded reinforcement in the composite and acts as the load transfer mechanism between the discrete reinforcement elements. **D3878**

3.1.14 *ply, n—in 2D laminar composites*, the constituent single layer as used in fabricating, or occurring within, a composite structure. **D3878**

3.1.15 *tow, n—in fibrous composites*, a continuous, ordered assembly of essentially parallel, collimated continuous filaments, normally without twist. (Synonym – roving) **D3878**

3.1.16 *unidirectional composite, n*—any fiber reinforced composite with all fibers aligned in a single direction. **D3878**

3.1.17 *woven fabric, n*—a fabric structure produced by the interlacing, in a specific weave pattern, of tows or yarns oriented in two or more directions.

3.1.17.1 *Discussion*—There are a large variety of 2D weave styles, e.g., plain, satin, twill, basket, crowfoot, etc.

3.1.18 *yarn, n—in fibrous composites*, a continuous, ordered assembly of essentially parallel, collimated filaments, normally with twist, and of either discontinuous or continuous filaments.

3.1.18.1 *single yarn, n*—an end in which each filament follows the same twist. **D3878**

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *1D, 2D, and 3D reinforcement, n*—a description of the orientation and distribution of the reinforcing fibers and yarns in a composite.

3.2.1.1 *Discussion*—In a 1D structure, all of the fibers are oriented in a single longitudinal (x) direction. In a 2D structure, all of the fibers lie in the x-y planes of the plate or bar or in the circumferential shells (axial and circumferential directions) of the rod or tube with no fibers aligned in the z or radial directions. In a 3D structure, the structure has fiber reinforcement in the x-y-z directions in the plate or bar and in the axial, circumferential, and radial directions in a tube or rod.

3.2.2 *axial tensile strength, n*—for a composite tube or solid round rod, the tensile strength along the long axis of the tube or rod. For a composite flat plate or rectangular bar, the tensile strength along the primary structural axis/direction.

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

3.2.3 *chemical vapor deposition or infiltration, n*—a chemical process in which a solid material is deposited on a substrate or in a porous preform through the decomposition or the reaction of gaseous precursors.

3.2.3.1 *Discussion*—Chemical vapor deposition is commonly done at elevated temperatures in a controlled atmosphere.

3.2.4 *fiber interface coating, n—in ceramic composites*, a coating applied to fibers to control the bonding between the fiber and the matrix.

3.2.4.1 *Discussion*—It is common practice in SiC-SiC composites to provide a thin (<3 micrometers) interface coating on the surface of the fibers/filaments to prevent strong bonding between the SiC fibers and the SiC matrix. A weak bond between the fiber and the matrix in the SiC-SiC composite permits the fibers to bridge matrix cracks and promotes mechanical toughness; a strong bond between the matrix and the fiber produces low strain, brittle failure. Fiber interface coatings with controlled composition, thickness, phase content, and morphology/microstructure are used to control that interface strength. Fiber interface coatings may be multilayered with different compositions and morphologies. (**1, 2**)[4]

3.2.5 *hot press and sinter densification, n—in SiC matrix composites*, a matrix production and densification process in which silicon carbide particulate in the preform are consolidated and sintered together to high density in a die press at high pressures and high temperatures.

3.2.5.1 *Discussion*—A sintering additive is often added to the silicon carbide powders to produce liquid phase sintering and promote/accelerate densification.

3.2.6 *infiltration and pyrolysis densification, n—in SiC matrix composites*, a matrix production and densification process in which a liquid silicone-organic polymer precursor is infiltrated/impregnated into the porous perform or the partially porous composite and pyrolyzed to form the silicon carbide matrix.

3.2.6.1 *Discussion*—Pyrolysis of the silicone-organic precursor in an inert atmosphere converts the precursor to a silicon carbide form with the desired purity and crystal structure. The infiltration/pyrolysis process may be iteratively repeated to fill the porosity and build up the density in the composite. (**3**)

3.2.7 *melt infiltration, n—in SiC matrix composites*, the matrix production and densification process in which molten silicon is infiltrated into a preform (containing SiC fibers and SiC and carbon particulate) and the molten silicon reacts with the free carbon to form a bonding silicon carbide matrix. (Synonyms – reaction sintering, liquid silicon infiltration) (**4**)

3.2.8 *primary structural axis, n—in a composite flat plate or rectangular bar*, the directional axis defined by the loading axis/direction with the highest required tensile strength.

3.2.8.1 *Discussion*—The primary structural axis is commonly the axis with the highest fiber loading. This axis may not be parallel with the longest dimension of the plate/bar/structure.

3.2.9 *pyrolysis, n—in SiC matrix composites*, the controlled thermal process in which a silicone-organic precursor is decomposed in an inert atmosphere to form the silicon carbide (SiC) matrix.

3.2.9.1 *Discussion*—Pyrolysis commonly results in weight loss and the release of hydrogen and hydrocarbon vapors.

3.2.10 *rectangular bar, n*—a solid straight rod with a rectangular cross-section, geometrically defined by a width, a thickness, and a long axis length.

3.2.11 *round rod, n*—a solid elongated straight cylinder, geometrically defined by an outer diameter and an axial length.

3.2.12 *round tube, n*—a hollow elongated cylinder, geometrically defined by a outer diameter, an inner diameter, and an axial length.

3.2.13 *silicon carbide–silicon carbide composite, n*—a ceramic matrix composite in which the reinforcing phase consists of continuous silicon carbide filaments in the form of fiber, continuous yarn, or a woven or braided fabric contained within a continuous matrix of silicon carbide. (**5-9**)

3.2.14 *silicon carbide fibers, n*—inorganic fibers with a primary (≥80 weight%) silicon carbide (stoichiometric SiC formula) composition.

3.2.14.1 *Discussion*—Silicon carbide fibers are commonly produced by two methods—the high temperature pyrolysis and sintering of silicone-organic precursor fibers in an inert atmosphere and the chemical vapor deposition of silicon carbide on a substrate filament. (**10, 11**)

3.2.15 *surface seal coatings, n*—an inorganic protective coating applied to the outer surface of a SiC-SiC composite component to protect against high temperature oxidation or corrosion attack, or both, or to improve wear and abrasion resistance. Such coatings are commonly hard, impermeable ceramic coatings.

4. Significance and Use

4.1 Composite materials consist by definition of a reinforcement phase/s in a matrix phase/s. The composition and structure of these constituents in the composites are commonly tailored for a specific application with detailed performance requirements. For fiber reinforced ceramic composites the tailoring involves the selection of the reinforcement fibers (composition, properties, morphology, interface coatings, etc.), the matrix (composition, properties, and morphology), the composite structure (component fractions, reinforcement architecture, interface coatings, porosity structure, microstructure, etc.), and the fabrication conditions (assembly, forming, densification, finishing, etc.). The final engineering properties (physical, mechanical, thermal, electrical, etc) can be tailored across a broad range with major directional anisotropy in the properties. (**5-9**)

4.2 This classification system assists the ceramic composite designer/user/producer in identifying and organizing different types of silicon carbide-silicon carbide (SiC-SiC) composites (based on fibers, matrix, architecture, physical properties, and mechanical properties) for structural applications. It is meant to assist the ceramic composite community in developing,

[4] The boldface numbers in parentheses refer to the list of references at the end of this standard.

selecting, and using SiC-SiC composites with the appropriate composition, construction, and properties for a specific application.

4.3 This classification system is a top level identification tool which uses a limited number of composites properties for high level classification. It is not meant to be a complete, detailed material specification, because it does not cover the full range of composition, architecture, physical, mechanical, fabrication, and durability requirements commonly defined in a full design specification. Guide C1793 provides direction and guidance in preparing a complete material specification for a given SiC-SiC composite component.

5. Silicon Carbide-Silicon Carbide Composites

5.1 Silicon carbide-silicon carbide composites are composed of silicon carbide fiber reinforcement in a silicon carbide matrix. The chemical and phase composition, microstructure, and properties of the SiC fibers and of the silicon carbide matrix, the fiber architecture (the shape and morphology of the fiber preform, multidimensional fiber distribution, and volume content of the fiber reinforcement), and the composite density and porosity are engineered to give the desired performance properties for the composite. The SiC fibers generally have a fiber interface coating to control the bonding and sliding between the SiC fiber and the SiC matrix. (**5-9**)

5.2 The physical, mechanical, and thermal properties of SiC-SiC composites are determined by the complex interaction of the constituents (fiber, interface coating, matrix, porosity) in terms of the constituent chemistry, phase composition, microstructure, properties, and fractional content; the fiber architecture; the fiber-matrix bonding, and the effect of fabrication on the constituent properties, morphology, and their physical interactions. These factors can be synergistically tailored to produce a structure/component with the desired mechanical, physical, and thermal properties. The SiC-SiC composite properties can be tailored for directional properties by the anisotropic architecture of the silicon carbide fiber reinforcement.

5.3 Silicon carbide fibers produced by the polymer precursor route are commonly small diameter (5-20 micrometers) continuous filaments. (**10**, **11**) The mechanical and thermal properties of the silicon carbide fibers are strongly dependent on the silicon carbide stoichiometry, oxygen and impurity levels, the phase composition and fractions, and the crystallite size and orientation in the fibers. These factors are determined by the precursor chemistry and the fabrication process conditions.

5.4 The silicon carbide fibers are commonly consolidated into high count multifilament tows which can be wound, wrapped, or layed-up into 1D structures, woven/layed-up/braided/knitted into 2D structures, or woven/braided/knitted/stitched into 3D structures. Each of these fiber structures are fabricated with defined fiber architectures, offering a wide range of bulk fiber content. Different fiber architectures may have marked reinforcement anisotropy, depending on the relative fiber content in each orthogonal direction.

NOTE 1—Many commercially available SiC-SiC composites consist of stacked fabric plies with a two dimensional woven fabric architecture. The SiC-SiC composite is densified to >90% density to produce a final structure with orthotropic or quasi-isotropic mechanical and thermal properties.

5.5 The silicon carbide matrix in SiC-SiC composites is commonly produced by one of four methods (**12**): *(1)* a chemical vapor infiltration process, *(2)* an iterative precursor liquid infiltration/pyrolysis process, *(3)* a silicon melt infiltration process, or *(4)* hot pressing and sintering of SiC powders. The four matrix formation processes use different precursors and different processing conditions, which produce differences in the chemistry, phase composition and fractions, crystallinity, morphology, and microstructure (density, pores, and cracks) in the silicon carbide matrix. Two or more of these matrix densification processes may be combined for a hybrid silicon carbide matrix.

5.6 In some SiC-SiC composite applications an inorganic surface seal coating is applied to the outer surface of the composite to protect against high temperature oxidation and corrosion attack or to improve wear and abrasion resistance. Such coatings are commonly hard, impermeable ceramic coatings.

5.7 The interaction of these four variable factor sets [*(1)* silicon carbide fiber type and properties; *(2)* fiber interface coating; *(3)* fiber content, tow structure, and architecture; *(4)* matrix composition and properties, phase content, crystallinity, density, morphology, and porosity] can produce SiC-SiC composites with a wide range of mechanical and physical properties, along with tailored anisotropic properties in the major directions.

6. Classification of Silicon Carbide-Silicon Carbide Composites

6.1 *General*—SiC-SiC composites for structural applications can be classified by fiber type, architecture class, matrix grade, physical properties, and mechanical properties.

6.2 *Fiber Types*—The SiC-SiC composites are *type* classified based on the stoichiometry and the fabrication method of the silicon carbide fiber.

6.2.1 *Type A*—>95 atomic % stoichiometric crystalline SiC by polymer precursor;

6.2.2 *Type B*—80-95 atomic % stoichiometric crystalline SiC by polymer precursor;

6.2.3 *Type C*—<80 atomic % stoichiometric crystalline SiC by polymer precursor; and

6.2.4 *Type D*—chemical vapor deposition based silicon carbide fibers.

6.3 *Architecture Class*—The SiC-SiC composites are *class* identified based on the fiber reinforcement architecture.

6.3.1 *Class 1*—One-dimensional (1D) filament winding or 1D layups of uniaxial tape;

6.3.2 *Class 2*—Laminates of two-dimensional (2D) fabric plies, 0-90 lay-ups of uniaxial tape, or 2-D braids/knits; and

6.3.3 *Class 3*—Three-dimensional (3D) woven, braided, or knitted fiber preforms.

NOTE 2—Some two dimensional laminates are reinforced by limited (<5% by fiber volume) through-thickness stitching/needling with fiber tows, sometimes called a 2.5D architecture. For the purposes of this specification, stitched/needled (2.5D) architectures are considered Class 3 (3D) composites.

6.4 *Matrix Grade*—The SiC-SiC composites are *grade* classified based on the method of matrix densification.

6.4.1 *Grade C*—Matrix based on chemical vapor infiltration/deposition (CVI/CVD) with gaseous precursors;

6.4.2 *Grade P*—Matrix based on polymer-infiltration and pyrolysis (PP) of silicone-organic precursors;

6.4.3 *Grade M*—Matrix based on silicon melt (MI) infiltration;

6.4.4 *Grade S*—Matrix based on hot-pressing and sintering (S) of silicon carbide powders; and

6.4.5 *Grade H*—Matrix based on a combination of two or more matrix process methods—CVI, PP, MI, and S based matrix processing.

6.5 Table 1 summarizes the classification codes for type, class, and grade of SiC-SiC composites.

6.6 *Physical Properties*—The three physical properties of primary interest for classification are fiber volume fraction, bulk density, and apparent porosity. Table 2 defines a system for classifying the fiber volume fraction, bulk density, and apparent porosity of SiC-SiC composites.

6.6.1 These physical properties shall be measured using the Test Methods cited in Table 2.

6.7 *Mechanical Properties*—The room temperature mechanical properties of primary classification interest are: *average ultimate tensile/hoop strength* and *average tensile/hoop modulus of elasticity* along the principal axis. Table 3 defines a system for classifying the two primary mechanical properties of SiC-SiC composite structures.

6.7.1 These tensile properties shall be measured using the Test Methods cited in Table 3. Averages shall be calculated from a minimum number of test specimens—ten specimens for tensile strength properties and five specimens for tensile modulus properties.

6.8 The SiC-SiC (SC2) composite materials classification code shall consist of the abbreviation SC2 followed by a hyphen, the type classification by a capital letter, the grade classification in Arabic numerals, the class by a capital letter, a hyphen, the physical property codes in an Arabic numeral-capital letter-Arabic numeral, a hyphen, and the mechanical property codes in two Arabic numerals.

6.8.1 *Examples of Classification Code Designations:*

6.8.1.1 *SC2-A2C-4D10-33*—Classification of a SiC-SiC composite material/component (*SC2*) with a 95 %+ stoichiometric polymer precursor (*A*) base silicon carbide fiber with a 2D (*2*) fiber architecture in a CVI matrix (*C*), a fiber volume fraction of 45 % (*4* = 40 to 45 %), a bulk density of 2.3 g/cc (*D* = 2.0 to 2.5 g/cc), an apparent porosity of 12 % (*10* = 10 to 15 %), an average ultimate tensile strength of 350 MPa (*3* = 300 to 399 MPa), and an average tensile modulus of 380 GPa (*3* = 300 to 399 GPa).

6.8.1.2 *SC2-B3M-3C5-12*—Classification of a SiC-SiC composite material/component (*SC2*) with a 80-95% stoichiometric polymer precursor (*B*) silicon carbide fiber with a 3D (*3*) fiber architecture in a silicon melt infiltration (*M*) base matrix, a fiber volume of 38 % (*3* = 30 to 40 %), a bulk density of 2.6 g/cc (*C* = 2.5 to 2.8 g/cc), an apparent porosity of 6 % (*5* = 5 to 10 %), an average ultimate tensile strength of 180 MPa (*1* = 100 to 199 MPa), and an average tensile modulus of 210 GPa (*2* = 200 to 299 GPa).

6.8.1.3 *SC2-D1S-5A2*-43*—Classification of a SiC-SiC composite material/component (*SC2*) with CVI base (*D*) silicon carbide fiber in a 1D (*1*) fiber architecture with a hot-press-sinter (*S*) base matrix, a fiber volume of 48 % (*5* = >45 %), a bulk density of 3.1 g/cc (*A* = >3.0 g/cc), an apparent porosity of <2 % (*2** = <2 %), an average ultimate tensile strength of 430 MPa (*4* = >400 MPa), and an average tensile modulus of 360 GPa (*3* = 300-399 GPa).

7. Keywords

7.1 classification; mechanical properties; physical properties; silicon carbide composites; silicon carbide fiber

TABLE 1 Classification Codes for SiC-SiC Composites for Structural Applications

Order	Property	Classification Codes				
1	Fiber Type	A – >95% Stoichiometric SiC Fibers by PP	B – 80-95% Stoichiometric SiC Fibers by PP	C – <80% Stoichiometric SiC Fibers by PP	D – CVI based SiC fibers	
2	Fiber Architecture Class	1 – Filament Wound or 1D laminate of uniaxial tapes	2 – 2D laminate of uniaxial tapes or 2D woven/braided/ knitted fabric plies	3 – 3D weave, braid, or knit		
3	Matrix Type Grade	C – Chemical Vapor Infiltration	P – Polymer-Infiltration and Pyrolysis	M – Silicon Melt Infiltration	S – Hot Press and Sinter	H – Hybrid of C, P, M, or S based Matrices

TABLE 2 Physical Property Classification Level Codes for SiC-SiC Composites

	Level Codes				
	5	4	3	2	1
Fiber Volume Bulk Fraction (%) by Calculation from Production Information	>45%	40-45%	30-39%	20-29%	<20%
	A	B	C	D	E
Bulk Density (g/cc) by Measurement (Test Method C559) and/or Immersion (Test Method C1039)	>3.0	2.8-2.99	2.5-2.79	2.0-2.49	<2.0
	2*	2	5	10	15
Apparent Porosity (%) by Immersion (Test Method C1039)	<2%	2-5%	5.1-10%	10.1-15%	>15%

TABLE 3 Mechanical Property Classification Level Codes for SiC-SiC Composites

NOTE 1—Four-point flexure strength and modulus properties are not an acceptable alternative to tensile properties for the classification process, because of the variability produced by different flexure specimen geometries and test configurations.

Mechanical Property	Geometry – Direction	Level Codes				
		4	3	2	1	1*
Average Ultimate Tensile or Hoop Strength[A] (MPa) by Test Methods C1275 and C1773	Plate / Bar – Primary Axis 0° Rod / Tube – Axial or Hoop[A]	>400 MPa	300-399 MPa	200-299 MPa	100-199 MPa	<100 MPa
		4	3	2	1	1*
Average Tensile or Hoop[A] Modulus (GPa) by Test Methods C1275, C1773, E111, C1198, and C1259	Plate / Bar – Primary Axis 0° Rod / Tube – Axial or Hoop[A]	>400 GPa	300-399 GPa	200-299 GPa	100-199 GPa	<100 GPa

[A] For composite tubes where hoop strength may be the primary strength requirement, the classification system may reference the hoop strength and hoop modulus, rather than the axial tensile strength and modulus. This will be marked by an "H" subscript on the Level Code: 5_H, 3_H, etc.

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