

## Standard Terminology Relating to Manufactured Carbon and Graphite<sup>1</sup>

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**across (or against) grain**, *n*—direction in a body with preferred orientation due to forming stresses that has the maximum *c*-axis alignment as measured in an X-ray diffraction test.

**agglomerate**, *n*—*in manufactured carbon and graphite product technology*, composite particle containing a number of grains.

**anisotropic nuclear graphite**, *n*—graphite in which the isotropy ratio based on the value of the coefficient of thermal expansion (25–500°C) is greater than 1.15.

**ash**, *n*—*in carbon and graphite technology*, residue remaining after oxidation of a carbon or graphite.

**binder**, *n*—substance, usually an organic material such as coal tar pitch or petroleum pitch, used to bond the coke or other filler material prior to baking.

**carbon**, *n*—element, number 6 of the periodic table of elements, electronic ground state  $1s^2 2s^2 2p^2$ .

**carbon**, *n*—*in carbon and graphite technology*, artifact consisting predominantly of the element carbon and possessing limited long range order.

DISCUSSION—The presence of limited long range order is usually associated with low electrical and thermal conductivity and difficult machinability when compared with graphite.

**carbon foam**, *n*—*in carbon and graphite technology*, porous carbon product containing regularly shaped, predominantly concave, homogeneously dispersed cells which interact to form a three-dimensional array throughout a continuum material of carbon, predominantly in the non-graphitic state. The final result is either an open or closed cell product.

DISCUSSION—In most foam, the cell wall thickness is less than half the average cell size.

**cell (bubble)**, *n*—*in carbon and graphite technology*, single small cavity formed by gaseous displacement in a precursor

material in its plastic state, and surrounded completely by its walls when formed. Cells can be open or closed.

DISCUSSION—After processing at high temperatures, the basic structure of the cell will remain even as the material converts from a plastic state to a rigid carbonaceous structure. Hence, the term cell will apply to a carbon product.

**cell count**, *n*—*in carbon and graphite technology, in closed-cell foams*, number of cells aligned in one plane in one linear inch, as determined by stereoscopic image analysis.

**cell size**, *n*—*in carbon and graphite technology*, average diameter of the cells in the final foam product.

**closed cell**, *n*—*in carbon and graphite technology*, cell totally enclosed by its walls and hence not interconnected with other cells. A closed cell foam is a foam consisting predominantly of closed cells.

**coke**, *n*—carbonaceous solid produced from coal, petroleum, or other materials by thermal decomposition with passage through a plastic state.

**compressive strength**, *n*—property of solid material that indicates its ability to withstand a uniaxial compressive load.

**defect**, *n*—*of a manufactured carbon or graphite product*, any irregularity in the chemistry, microstructure, or macrostructure.

**defective**, *adj*—having flaws or dimensional deviations greater than acceptable for the intended use.

**electrographite**, *n*—*in carbon and graphite technology*, synonym for manufactured graphite.

**extruded**, *v*—formed by being forced through a shaping orifice as a continuous body.

**filler**, *n*—*in manufactured carbon and graphite product technology*, carbonaceous particles comprising the base aggregate in an unbaked green-mix formulation.

**flaw**, *n*—defect sufficiently greater than those typical of the morphology of a carbon or graphite body to influence a property.

**flexural strength**, *n*—property of solid material that indicates its ability to withstand a flexural or transverse load.

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**flow line**, *n*—defect induced by discontinuous flow velocities during forming of molded or extruded bodies.

**grade**, *n*—designation given a material by a manufacturer such that it is always reproduced to the same specifications established by the manufacturer.

**grain**, *n*—*in manufactured (synthetic) carbon and graphite*, particle of filler material (usually coke or graphite) in the starting mix formulation. Also referred to as granular material, filler particle, or aggregate material. The term is also used to describe the general texture of a carbon or graphite body, as in the descriptions listed below:

*coarse grained*, *adj*—containing grains in the starting mix that are substantially greater than 4 mm in size.

*fine grained*, *adj*—containing grains in the starting mix that are generally less than 100  $\mu\text{m}$  in size.

*medium grained*, *adj*—containing grains in the starting mix that are generally less than 4 mm in size.

*microfine grained*, *adj*—containing grains in the starting mix that are generally less than 2  $\mu\text{m}$  in size.

*superfine grained*, *adj*—containing grains in the starting mix that are generally less than 50  $\mu\text{m}$  in size.

*ultrafine grained*, *adj*—containing grains in the starting mix that are generally less than 10  $\mu\text{m}$  in size.

DISCUSSION—All of the above descriptions relate to the generally accepted practice of measuring the sizing fractions with a criterion that 90 % of the grains will pass through the stated screen size in a standard particle sizing test.

**graphene layer**, *n*—*in carbon and graphite technology*, single carbon layer of the graphite structure, describing its nature by analogy to a polycyclic aromatic hydrocarbon of quasi-infinite size.

DISCUSSION—The term graphite designates a modification of the chemical element carbon in which planar sheets of carbon atoms, each atom bound to three neighbors in a honeycomb-like structure, are stacked in a three dimensional regular order. For a single layer, it is not correct to use the term graphite, which implies a three dimensional structure.

**graphite**, *n*—allotropic crystalline form of the element carbon, occurring as a mineral, commonly consisting of a hexagonal array of carbon atoms (space group P 6<sub>3</sub>/mmc) but also known in a rhombohedral form (space group R 3m).

**graphite**, *n*—*in carbon and graphite technology*, material consisting predominantly of the element carbon and possessing extensive long-range three-dimensional crystallographic order as determined by X-ray diffraction studies.

DISCUSSION—The presence of long-range order is usually accompanied with high electrical and thermal conductivity within the hexagonal plane. This results in a material having relatively easy machinability when compared to non-graphitic materials. The use of the term *graphite* without reporting confirmation of long-range crystallographic order should be avoided as it can be misleading.

**graphite foam**, *n*—*in carbon and graphite technology*, porous graphite product containing regularly shaped, predominantly concave, homogeneously dispersed cells which interact to form a three-dimensional array throughout a continuum

material of carbon, predominantly in the graphitic state. The final result is either an open or closed cell product.

DISCUSSION—In most foam, the cell wall thickness is less than half the average cell size.

**graphitic**, *adj*—*in carbon and graphite technology*, all varieties of substances consisting predominantly of the element carbon in the allotropic form of graphite irrespective of the presence of structural defects.

DISCUSSION—The use of the term graphitic is justified if three-dimensional hexagonal crystalline long-range order can be detected in the material by X-ray diffraction methods, independent of the volume fraction and the homogeneity of distribution of such crystalline domains. Otherwise, the term non-graphitic should be used.

**graphitizable carbon**, *n*—*in carbon and graphite technology*, non-graphitic carbon, which, upon graphitization, converts into graphitic carbon (also known as a soft carbon).

**graphitization**, *n*—*in carbon and graphite technology*, solid-state transformation of thermodynamically unstable non-graphitic carbon into graphite by thermal treatment.

DISCUSSION—The degree of graphitization is a measure of the extent of long-range 3D crystallographic order as determined by diffraction studies only. The degree of graphitization affects many properties significantly, such as thermal conductivity, electrical conductivity, strength, and stiffness.

DISCUSSION—A common, but incorrect, use of the term graphitization is to indicate a process of thermal treatment of carbon materials at  $T > 2200^{\circ}\text{C}$  regardless of any resultant crystallinity. The use of the term graphitization without reporting confirmation of long range three dimensional crystallographic order determined by diffraction studies should be avoided, as it can be misleading.

**graphitizing (nuclear grade) isotropic/near-isotropic coke**—a coke, which under reflected light microscopy, shows a fine mosaic texture where the individual microscopic domains show optical activity as the stage is rotated when both the polarizer and analyzer are in a crossed position in the optical path of the microscope.

DISCUSSION—The isotropic coke with optical domains of  $\sim 20$  microns is, crucially, a coke that develops three-dimensional order on heat treatment to temperatures  $>2400^{\circ}\text{C}$ , and hence may be described as graphitic. Furthermore, graphite produced from such a coke exhibits a CTE in the range of  $3.5 \times 10^{-6}$  to  $5.5 \times 10^{-6}$  (25 to  $500^{\circ}\text{C}$ ), and is isotropic in the sense that the ratio of the ag/wg CTE (25 to  $500^{\circ}\text{C}$ ) is yielding between 1.00 and 1.10. Similarly, graphite produced from a near-isotropic coke is defined as yielding graphite where the ag/wg CTE (25 to  $500^{\circ}\text{C}$ ) is between 1.10 and 1.15. The precursors to a graphitizing isotropic coke form fluid mesophase on thermal conversion to a solid graphitizable carbon.

**green carbon**, *n*—formed, but unfired carbon body.

**hard carbon**, *n*—see *non-graphitizable carbon*.

**hardness**, *n*—resistance of a material to deformation, particularly permanent deformation, indentation, or scratching.

**impervious carbon**, *n*—same as impervious graphite with the exception that the base stock has not been graphitized.

**impervious graphite**, *n*—manufactured graphite that has been impregnated with a resinous material to make the final article impervious to liquids in the recommended operating range.

**impregnation**, *n*—partial filling of the open pore structure with another material.

**isotropic**, *adj*— *in carbon and graphite technology*, having an isotropy ratio of 0.9 to 1.1 for a specific property of interest.

**isotropic nuclear graphite**, *n*—graphite in which the isotropy ratio based on the coefficient of thermal expansion (25–500°C) is 1.00–1.10.

**isotropy ratio**, *n*—*in carbon and graphite technology*, ratio of a given property value in the against grain direction to its corresponding value in the with grain direction (for example, the ratio of coefficients of thermal expansion).

**lamination**, *n*—line of demarcation or elongated void generally parallel to the principal grain direction of a carbon or graphite body.

**longitudinal sonic pulse**, *n*—sonic pulse in which the displacements are in the direction of propagation of the pulse.

**machinability**, *n*—measure of the ease with which a material can be shaped with the aid of cutting or abrasive tools.

**manufactured carbon**, *n*—bonded granular carbon body whose matrix has been subjected to a temperature typically between 900 and 2400°C.

**manufactured graphite**, *n*—bonded granular carbon body whose matrix has been subjected to a temperature typically in excess of 2400°C and whose matrix is thermally stable below that temperature.

**molded**, *v*—formed in a closed die by the application of external pressure.

**natural graphite**, *n*—*in carbon and graphite technology*, material consisting predominantly of graphitic carbon, which forms in the earth's crust as the result of igneous or metamorphic processes acting on carbonaceous materials.

DISCUSSION—The degree of crystalline perfection in these materials may vary. Natural graphite may contain significant quantities of gangue materials, either attached to or intercalated with graphitic carbon.

**near-isotropic nuclear graphite**, *n*—graphite in which the isotropy based on the coefficient of thermal expansion (25–500°C) is 1.10–1.15.

**non-graphitizable carbon**, *n*—*in carbon and graphite technology*, carbon which cannot be transformed into graphitic carbon solely by heat treatment up to 3000°C under inert atmosphere or reduced pressure (also known as a hard carbon).

**non-graphitizing isotropic coke**—a coke, which under reflected light microscopy shows no mosaic texture and no optical activity when both the polarizer and analyzer are in a crossed position in the optical path of the microscope as the stage is rotated.

DISCUSSION—The optically inactive isotropic coke is a coke that does not develop three-dimensional order on heat treatment to temperatures >2400°C, and hence may not be described as graphitic. The precursors to a non-graphitizing isotropic coke do not form fluid mesophase on

thermal conversion to a solid carbon. (There is the exceptional case of anthracite coal which is graphitizable but does not pass through a fluid mesophase stage.)

**open cell**, *n*—*in carbon and graphite technology*, cell that is not totally enclosed in its walls and hence interconnected with other cells. An open-cell foam is a foam consisting predominantly of open or connected cells.

**orientation (of a crystal)**, *n*—angular position of a crystal described by the angles which certain crystallographic axes make with the frame of reference.

**orientation (of a grain)**, *n*—angular position of a grain described by the angles which a defined set of axes of the grain make with the stated frame of reference. Generally used to characterize the axis of the grain that has the largest physical extent, for example, in a grain of needle coke.

**orientation (of an object)**, *n*—angular position of an object described by the angles which a defined set of axes or surfaces of the object make with the frame of reference.

**oxidation of carbon**, *n*—chemical combination of carbon with oxygen or oxygen-containing compounds.

**particle sizing**, *v*—segregation of granular material into specified particle size ranges.

**penetration**, *n*—depths to which one material extends into or penetrates another.

**permeability**, *n*—property measured by the rate of passage of a fluid under a pressure gradient through a material.

**pore**, *n*—see *void*.

**pore**, *n*—*in carbon and graphite technology*, in a carbon or graphite foam, passage that interconnects two cells.

**pore count**, *n*—*in carbon and graphite technology*, in open-cell foams, number of pores aligned in one plane in one linear inch, as determined by stereoscopic image analysis.

**porosity**, *n*—percentage of the total volume of a material occupied by both open and closed pores.

**preferred orientation**, *n*—*in manufactured carbon and graphite product technology*, alignment in the crystal or defect structure of a body leading to variations in physical properties as a function of direction; normally referenced to an orthogonal system where one of the axes is the working direction.

**pulse travel time ( $T_p$ )**, *n*—total time, measured in seconds, required for the sonic pulse to traverse the specimen being tested, and for the associated electronic signals to reverse the circuits of the pulse-propagation circuitry.

**pyrolytic graphite**, *n*—*in carbon and graphite technology*, artifact consisting predominantly of graphite which was deposited as a solid on a hot surface by cracking of gaseous or liquid hydrocarbons.

**reactivity**, *n*—rate at which another material will form compounds with carbon or graphite.

**reticulated foam**, *n*—in carbon and graphite technology, foam with a ligamentous structure rather than a spherical pore structure.

**soft carbon**, *n*—see *graphitizable carbon*.

**surface finish**, *n*—geometric irregularities in the surface of a solid material. Measurement of surface finish shall not include inherent structural irregularities unless these are the characteristics being measured.

**tensile strength**, *n*—property of solid material that indicates its ability to withstand a uniaxial tensile load.

**ultimate tensile strength**, *n*—highest load attained during a tensile test, converted to unit stress based on the original cross-section area of the tensile test specimen.

**void**, *n*—unfilled space enclosed within an apparently solid carbon or graphite body.

**with grain**, *n*—direction in a body with preferred orientation due to forming stresses that has the maximum *a*-axis alignment as measured in an X-ray diffraction test.

**working direction**, *n*—in manufactured carbon and graphite product technology, direction of applied force used in forming a solid body; generally the direction of applied molding pressure for a uniaxially molded material and the extrusion direction for an extruded material.

**zero time ( $T_0$ )**, *n*—travel time (correction factor), measured in seconds, associated with the electronic circuits in the pulse propagation system.

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