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RECOMMENDED TERMINOLOGY FOR THE DESCRIPTION OF CARBON AS A SOLID

(IUPAC Recommendations 1995)

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Recommended terminology for the description of carbon as a solid (IUPAC Recommendations 1995)

Synopsis - This document deals with the recommended terminology for the description of carbon as a solid as used in the science and technology of carbon and graphite materials. The glossary also contains terms describing related materials, such as precursors for the production of carbon materials, and the processes used in their production. In all, 114 terms are defined, and comments and cross-references are added as notes where appropriate.

PREFACE

Carbon as a solid covers all natural and synthetic substances consisting mainly of atoms of the element carbon, such as single crystals of diamond and graphite, as well as the full variety of carbon and graphite materials.

The terminology used so far is mainly based on technological tradition and on the standardized characterization methods of decades of industrial experience.

Because of the increasing interdisciplinary importance of this group of materials in science and technology, it is obvious that clear definitions of the corresponding terms and modern methods for characterization which are acceptable for all those working in the field are required.

As a first step IUPAC has taken responsibility for recommendations concerning the terminology of "Carbon as a Solid", that are consistent with the scientific nomenclature. These recommendations outlined in the following paper have been prepared by the IUPAC subcommittee SC-1 within the IUPAC commission II /3 (High Temperature and Solid State Chemistry) in cooperation with specialists in carbon science and industry from all over the world.

A total of 114 terms are described in this compilation and the descriptions are supplemented by notes. In so far as is possible, the terms used in the descriptions and notes are self-explanatory but they are cross-referenced where appropriate for ease of use of the glossary.

Note:
A description of FULLERENE is not included in the list of terms since it is anticipated, following consultation with Chemical Abstracts Service, that IUPAC will issue provisional recommendations on Fullerene Nomenclature and Terminology early in 1995.

LIST OF TERMS

ACETYLENE BLACK
ACHESON GRAPHITE
ACTIVATED CARBON
ACTIVATED CHARCOAL
AGRANULAR CARBON
AMORPHOUS CARBON
ARTIFICIAL GRAPHITE
BAKING
BINDER
BINDER COKE
BROOKS AND TAYLOR STRUCTURE IN THE CARBONACEOUS MESOPHASE
BULK MESOPHASE
CALCINED COKE

CARBON
CARBON ARTIFACT
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COALIFICATION
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DELAYED COKE
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FIBROUS CARBON
FILAMENTOUS CARBON
FILLER
FILLER COKE
FLUID COKE
FULLERENES
FURNACE BLACK
GAS PHASE-GROWN CARBON FIBRES
GLASS-LIKE CARBON
GRANULAR CARBON
GRAPHENE LAYER
GRAPHITE
GRAPHITE ELECTRODE
GRAPHITE FIBRES
GRAPHITE MATERIAL
GRAPHITE WHISKER
GRAPHITIC CARBON
GRAPHITIZABLE CARBON
GRAPHITIZATION
GRAPHITIZATION HEAT TREATMENT
GRAPHITIZED CARBON
GREEN COKE
HARD AMORPHOUS CARBON FILMS
HEXAGONAL GRAPHITE
HIGH-PRESSURE GRAPHITIZATION
HIGHLY ORIENTED PYROLYTIC GRAPHITE
ISOTROPIC CARBON
ISOTROPIC PITCH-BASED CARBON FIBRES
LAMP BLACK
MESOGENIC PITCH
MESOPHASE PITCH
MESOPHASE PITCH-BASED CARBON FIBRES
METALLURGICAL COKE
MICROPOROUS CARBON
MPP-BASED CARBON FIBRES
NATURAL GRAPHITE
NEEDLE COKE
NON-GRAPHITIC CARBON
NON-GRAPHITIZABLE CARBON
NUCLEAR GRAPHITE
PAN-BASED CARBON FIBRES
PARTICULATE CARBON
PETROLEUM COKE
PETROLEUM PITCH
PITCH
PITCH-BASED CARBON FIBRES
POLYCRYSTALLINE GRAPHITE
POLYGRANULAR CARBON
POLYGRANULAR GRAPHITE
PREMIUM COKE
PUFFING
PUFFING INHIBITOR
PYROLYTIC CARBON
PYROLYTIC GRAPHITE
RAW COKE
RAYON-BASED CARBON FIBRES
REGULAR COKE
RHOMBOHEDRAL GRAPHITE
SEMICOKE
SOOT
SPHERICAL CARBONACEOUS MESOPHASE
STABILIZATION TREATMENT OF THERMO PLASTIC PRECURSOR FIBRES FOR CARBON FIBRES
STRESS GRAPHITIZATION
SYNTHETIC GRAPHITE
THERMAL BLACK

DESCRIPTIONS OF THE TERMS

ACETYLENE BLACK

Description:
ACETYLENE BLACK is a special type of CARBON BLACK formed by an exothermic decomposition of acetylene. It is characterized by the highest degree of aggregation and crystalline orientation when compared with all types of CARBON BLACK:
See: CARBON BLACK

Note:
ACETYLENE BLACK must not be confused with the CARBON BLACK produced as a by-product during the production of acetylene in the electric arc process.
See: CARBON BLACK

ACHESON GRAPHITE

Description:
ACHESON GRAPHITE is a SYNTHETIC GRAPHITE made by the Acheson process.
See: SYNTHETIC GRAPHITE

Note:
Reference to Acheson in combination with SYNTHETIC GRAPHITE honours the inventor of the first technical GRAPHITIZATION. Today the term ACHESON GRAPHITE, however, is of historical interest only because it no longer covers the plurality of SYNTHETIC GRAPHITE.
See: SYNTHETIC GRAPHITE

ACTIVATED CARBON

Description:
ACTIVATED CARBON is a porous CARBON MATERIAL, a CHAR which has been subjected to reaction with gases, sometimes with the addition of chemicals, *e.g.* $ZnCl_2$, before, during or after CARBONIZATION in order to increase its adsorptive properties.
See: CARBON MATERIAL
CARBONIZATION
CHAR

Notes:
ACTIVATED CARBONS have a large adsorption capacity, preferably for small molecules, and are used for purification of liquids and gases. By controlling the process of CARBONIZATION and activation, a variety of active carbons having different porosity can be obtained. ACTIVATED CARBONS are used mainly in granular and powdered forms, but can also be produced in textile form by controlled CARBONIZATION and activation of textile fibres. Other terms used in the literature: active carbons, active charcoals.
See: CARBONIZATION

ACTIVATED CHARCOAL

Description:
ACTIVATED CHARCOAL is a traditional term for ACTIVATED CARBON.
See: ACTIVATED CARBON

AGRANULAR CARBON

Description:
AGRANULAR CARBON is a monogranular or monolithic CARBON MATERIAL with homogeneous microstructure which does not exhibit any structural components distinguishable by optical microscopy.
See: CARBON MATERIAL

Notes:
The above definition of a homogeneous microstructure does not pertain to pores and structural components which may be visible by contrast differences in optical microscopy with

polarized light. As a consequence, GLASS-LIKE CARBON with visible pores is still an AGRANULAR CARBON. The same is true, for instance, for PYROLYTIC CARBON with preferred orientation, such as conical or lamellar structures, visible in optical microscopy with polarized light. The use of the term AGRANULAR CARBON is not restricted to bulk materials of a minimum size. Only PARTICULATE CARBON should be excluded even if the isolated particles exhibit a homogeneous microstructure.

See: GLASS-LIKE CARBON
PARTICULATE CARBON
PYROLYTIC CARBON

AMORPHOUS CARBON

Description:

AMORPHOUS CARBON is a CARBON MATERIAL without long-range crystalline order. Short-range order exists, but with deviations of the interatomic distances and/or interbonding angles with respect to the graphite lattice as well as to the diamond lattice.

See: CARBON MATERIAL
DIAMOND-LIKE CARBON

Notes:

The term AMORPHOUS CARBON is restricted to the description of CARBON MATERIALS with localized π-electrons as described by P.W.ANDERSON [*Phys.Rev.* **109**, 1492 (1958)]. Deviations in the C-C distances greater than 5% (*i.e.* $\pm \Delta x/x_o > 0.05$, where x_o is the interatomic distance in the crystal lattice for the sp^2 as well as for the sp^3 configuration) occur in such materials, as well as deviations in the bond angles because of the presence of "dangling bonds".

Above description of AMORPHOUS CARBON is not applicable to CARBON MATERIALS with two-dimensional structural elements present in all pyrolysis residues of carbon compounds as polyaromatic layers with a nearly ideal interatomic distance of a = 142 pm and an extension greater than 1000 pm.

See: CARBON MATERIAL

ARTIFICIAL GRAPHITE

Description:

The term ARTIFICIAL GRAPHITE is often used in place of SYNTHETIC GRAPHITE.

See: SYNTHETIC GRAPHITE

Note:

This term is not recommended.

BAKING

Description:

The process in which the carbonaceous BINDER, usually COAL TAR PITCH or PETROLEUM PITCH, as part of a shaped CARBON MIX is converted to CARBON yielding a rigid carbon body by the slow application of heat. The process can take as little as 14 days in coarse-grained, electrothermic grades (low binder level) and as long as 36 days in ultra-fine-grained, speciality grades (high binder level). The final baking temperature can be in the range of 1100 K - 1500 K, depending on the grade.

See: BINDER
CARBON
COAL TAR PITCH
PETROLEUM PITCH

BINDER

Description:

A BINDER is usually a COAL TAR PITCH or PETROLEUM PITCH (but may include thermosetting resins or MESOPHASE PITCH powders) which, when mixed with a BINDER COKE or a FILLER, constitutes a CARBON MIX. This is used in preparation of the formation of shaped green bodies and subsequently CARBON ARTIFACTS.

See: BINDER COKE
CARBON ARTIFACT
CARBON MIX
COAL TAR PITCH
MESOPHASE PITCH
PETROLEUM PITCH
PITCH

BINDER COKE

Description:
BINDER COKE is a constituent of a carbon (or ceramic) artifact resulting from CARBONIZATION of the binder during baking.
See: CARBONIZATION

Note:
PITCHES are mainly used as binders, *i.e.* as precursors for BINDER COKES, but the term BINDER should include any carbonaceous binder material, for example thermosetting resins such as poly(furfuryl alcohol) or phenolics and similar compounds which may form a CHAR during CARBONIZATION.
See: CARBONIZATION
CHAR

BROOKS AND TAYLOR STRUCTURE IN THE CARBONACEOUS MESOPHASE

Description:
The BROOKS AND TAYLOR STRUCTURE IN THE CARBONACEOUS MESOPHASE refers to the structure of the anisotropic spheres which precipitate from isotropic PITCH during pyrolysis. The structure of the spheres consists of a lamellar arrangement of aromatic molecules in parallel layers which are perpendicular to the polar axis of the sphere and which are perpendicular to the mesophase-isotropic phase interface.

Note:
The term BROOKS AND TAYLOR STRUCTURE is recommended to describe the particular lamellar morphology of the spherules most commonly precipitated from pyrolyzed PITCH. The term honours the workers who first recognized the significance of CARBONACEOUS MESOPHASE to carbon science and technology and who first defined this spherical morphology. The term BROOKS AND TAYLOR STRUCTURE does not cover all structures found in the spherical mesophase, because other lamellar arrangements have been observed.
See: CARBONACEOUS MESOPHASE
PITCH

BULK MESOPHASE

Description:
BULK MESOPHASE is a continuous anisotropic phase formed by coalescence of mesophase spheres. BULK MESOPHASE retains fluidity and is deformable in the temperature range up to about 770 K, and transforms into GREEN COKE by further loss of hydrogen or low-molecular-weight species.
See: GREEN COKE

Note:
This BULK MESOPHASE can sometimes be formed directly from the isotropic PITCH without observation of intermediate spheres.
See: PITCH

CALCINED COKE

Description:

CALCINED COKE is a PETROLEUM COKE or COAL-DERIVED PITCH COKE obtained by heat treatment of GREEN COKE to about 1600 K. It will normally have a hydrogen content of less than 0.1 wt.%.

See: COAL-DERIVED PITCH COKE
GREEN COKE
PETROLEUM COKE

Note:

CALCINED COKE is the main raw material for the manufacture of POLYGRANULAR CARBON and POLYGRANULAR GRAPHITE products (*e.g.* CARBON and GRAPHITE ELECTRODES).

See: CARBON ELECTRODE
POLYGRANULAR CARBON
POLYGRANULAR GRAPHITE

CARBON

Description:

CARBON is the element number 6 of the Periodic Table of Elements (electronic ground state $1s^2\,2s^2\,2p^2$).

Note:

For description of the various types of CARBON AS A SOLID the term CARBON should be used only in combination with an additional noun or a clarifying adjective.

See: AMORPHOUS CARBON
CARBON FIBRES
CARBON MATERIAL
GLASS-LIKE CARBON
GRAPHITIC CARBON
NON-GRAPHITIC CARBON
PYROLYTIC CARBON

CARBON ARTIFACT

Description:

CARBON ARTIFACT means an "artificially produced" solid body which consists mainly of carbonaceous material in a distinct shape.

Note:

Sometimes this term is also used for artificially (in the sense of technically) produced non-shaped CARBON MATERIALS such as COKE, blacks, *etc.* This application of the term CARBON ARTIFACT is not recommended. Synonyms to the term CARBON ARTIFACT are: "artificial carbon article" or "artificial carbon body".

See: CARBON MATERIAL
COKE

CARBON BLACK

Description:

CARBON BLACK is an industrially manufactured COLLOIDAL CARBON material in the form of spheres and of their fused aggregates with sizes below 1000 nm.

See: COLLOIDAL CARBON

Notes:

CARBON BLACK is a commercial product manufactured by thermal decomposition, including detonation, or by incomplete combustion of carbon hydrogen compounds and has a well-defined morphology with a minimum content of tars or other extraneous materials.

For historical reasons, however, CARBON BLACK is popularly but incorrectly regarded as a form of SOOT. In fact, in many languages, the same word is used to designate both materials. CARBON BLACK is manufactured under controlled conditions, whereas SOOT is randomly formed. They can be distinguished on the basis of tar, ash content and impurities. Attempts in the literature to create a general term, "aciniform carbon", which would cover both CARBON BLACK and SOOT, is not yet generally accepted.

See: SOOT

CARBON-CARBON COMPOSITE

Description:

A CARBON-CARBON COMPOSITE is a CARBON FIBRE-reinforced carbon matrix material. The carbon matrix phase is typically formed by solid, liquid or gaseous pyrolysis of an organic precursor material. The matrix is either a GRAPHITIZABLE CARBON or NON-GRAPHITIZABLE CARBON, and the carbonaceous reinforcement is fibrous in form. The composite may also contain other components in particulate or fibrous forms.

See: CARBON FIBRE
GRAPHITIZABLE CARBON
NON-GRAPHITIZABLE CARBON

CARBON CENOSPHERES

Description:

CARBON CENOSPHERES are porous or hollow carbonaceous sphere-like particles (frequently in the size range of a few to several hundreds of µm diameter) formed during pyrolysis, also in the course of combustion, of carbonaceous liquid droplets (*e.g.* heavy fuel) or solid particles (*e.g.* coal).

CARBON CLOTH

Description:

CARBON CLOTH is a textile material consisting of CARBON FIBRES oriented at least in two directions.

See: CARBON FIBRES

Note:

CARBON CLOTH is not necessarily woven.

CARBON ELECTRODE

Description:

A CARBON ELECTRODE is an electrode for an electrical application. In its green state it comprises granular carbon material bound with pitch. The GRANULAR CARBON material may be either NEEDLE COKE, fine-grained or isotropic coke or reclaimed GRAPHITE powder. Electrodes for use in steel production can only be manufactured from NEEDLE COKE, and the green electrodes are fired at temperatures above around 2800 K to produce highly graphitic electrodes (GRAPHITE ELECTRODES). The other granular carbon materials may be used for aluminium electrodes where the duty is not so severe, and the green electrodes are generally fired to lower temperatures.

See: GRANULAR CARBON
GRAPHITIC CARBON
GRAPHITIZATION HEAT TREATMENT
ISOTROPIC CARBON
NEEDLE COKE

Note:

In both cases it is essential that the GRANULAR CARBONS and the PITCH binders used in the production of the green electrodes have a low sulfur content as the release of sulfur during the high-temperature firing can lead to the production of significant porosity.

See: PUFFING

CARBON FELT

Description:

CARBON FELT is a textile material consisting of, in approximation, randomly oriented and intertwined CARBON FIBRES.

See: CARBON FIBRES

Note:

CARBON FELTS are usually fabricated by CARBONIZATION of organic felts but they can also be produced from short CARBON FIBRES.

See: CARBON FIBRES
CARBONIZATION

CARBON FIBRE

Description:

CARBON FIBRES are fibres (filaments, tows, yarns, rovings) consisting of at least 92% (mass fraction) CARBON, usually in the NON-GRAPHITIC state.

See: CARBON
NON-GRAPHITIC CARBON

Notes:

CARBON FIBRES are fabricated by pyrolysis of organic precursor fibres or by growth from gaseous hydrocarbons. The use of the term GRAPHITE FIBRES instead of CARBON FIBRES as often observed in the literature is incorrect and should be avoided. The term GRAPHITE FIBRES is justified only if three-dimensional crystalline order is confirmed, *e.g.* by X-ray diffraction measurements.

See: GRAPHITE FIBRES

CARBON FIBRE FABRICS

Description:

CARBON FIBRE FABRICS are woven textile materials made of CARBON FIBRES.

See: CARBON FIBRES

CARBON FIBRES TYPE HM

Description:

CARBON FIBRES TYPE HM (HIGH MODULUS) are CARBON FIBRES with a value of Young's modulus (tensile modulus) larger than 300 GPa (nearly 30% of the C_{11} elastic constant of a graphite single crystal).

See: CARBON FIBRES

Notes:

The level of the tensile modulus of CARBON FIBRES is controlled by the degree of preferred orientation of the layer planes in the direction parallel to the fibre axis. C_{11}, the elastic constant of graphite single crystals in the direction of the layer planes is 1060 ± 20 GPa.

In general, the ratio of tensile strength to tensile modulus is smaller than $1 \cdot 10^{-2}$ for CARBON FIBRES TYPE HM (but the tensile strength is influenced by flaws in the fibres and may be improved in the future).

CARBON FIBRES TYPE UHM (ULTRA-HIGH MODULUS) have moduli of elasticity in excess of 600 GPa, surpassing 50% of the theoretical C_{11} number. Such high values of Young's modulus can be achieved most readily in MESOPHASE PITCH-BASED CARBON FIBRES (MPP-based carbon fibres).

See: CARBON FIBRES

CARBON FIBRES TYPE HT

Description:

CARBON FIBRES TYPE HT are CARBON FIBRES with values of Young's modulus between 150 and 275 to 300 GPa. The term HT, referring to high tensile strength, was early applied because fibres of this type display the highest tensile strengths.

See: CARBON FIBRES

Notes:
The disposition of boundaries between the fibre types is somewhat arbitrary.
For CARBON FIBRES TYPE HT, the values of the strength-to-stiffness ratio are typically larger than $1.5 \cdot 10^{-2}$. The tensile strength of CARBON FIBRES is flaw-controlled, however, and therefore the measured values increase strongly as the diameter of the filaments is decreased.

See: CARBON FIBRES
CARBON FIBRES TYPE IM

CARBON FIBRES TYPE IM

Description:
The CARBON FIBRES TYPE IM (INTERMEDIATE MODULUS) are related to CARBON FIBRES TYPE HT because of the comparable values of tensile strength, but are characterized by greater stiffness (Young's modulus up to approximately 35% of the theoretical C_{11} value).

See: CARBON FIBRES
CARBON FIBRES TYPE HT

Notes:
The tensile modulus (Young's modulus) varies between *ca.* 275 and 350 GPa, but the disposition of the boundaries is somewhat arbitrary. The relatively high ratio of tensile strength to tensile modulus, typcally above $1 \cdot 10^{-2}$, in CARBON FIBRES TYPE IM, in spite of an increase of Young's modulus, requires a further increase of strength, which is achievable by a significant reduction of the monofilament diameter down to about 5 μm. Such small filament diameters are typical of CARBON FIBRES TYPE IM.

CARBON FIBRES TYPE LM

Description:
CARBON FIBRES TYPE LM (LOW MODULUS) are CARBON FIBRES with isotropic structure, tensile modulus values as low as 10% of the C_{11} values of the graphite single crystal, and low strength values.

See: CARBON FIBRES

Notes:
The term CARBON FIBRES TYPE LM is sometimes used for various types of isotropic CARBON FIBRES known as PITCH-BASED or RAYON-BASED CARBON FIBRES that have not been subjected to hot-stretching. Such fibres are not used for reinforcement purposes in high-performance composites.

See: CARBON FIBRES
PITCH-BASED CARBON FIBRES
RAYON-BASED CARBON FIBRES

CARBON FIBRES TYPE UHM

Description:
CARBON FIBRES TYPE UHM (ULTRA-HIGH MODULUS) designates a class of CARBON FIBRES having very high values of Young's modulus larger than 600 GPa (*i.e.* greater than 55% of the theoretical C_{11} value of GRAPHITE).

See: CARBON FIBRE
CARBON FIBRE TYPE HM
GRAPHITE

CARBON MATERIAL

Description:
CARBON MATERIAL is a solid high in content of the element CARBON and structurally in a NON-GRAPHITIC state.

See: CARBON
NON-GRAPHITIC CARBON

Notes:
The use of the term CARBON as a short term for a material consisting of NON-GRAPHITIC CARBON is incorrect. The use of the term CARBON without a second noun or a clarifying adjective should be restricted to the chemical element carbon. The term CARBON can be used in combination with other nouns or clarifying adjectives for special types of CARBON MATERIALS (CARBON ELECTRODE, CARBON FIBRES, PYROLYTIC CARBON, GLASS-LIKE CARBON and others).

See: CARBON
CARBON ELECTRODE
CARBON FIBRES
GLASS-LIKE CARBON
NON-GRAPHITIC CARBON
PYROLYTIC CARBON

CARBON MIX

Description:
CARBON MIX is a mixture of FILLER COKE, *e.g.* grains and/or powders of solid CARBON MATERIALS, and a carbonaceous BINDER and selected additives, prepared in heated mixers at temperatures in the range of 410 K - 445 K as a preliminary step for the formation of shaped green bodies.

See: BINDER
CARBON MATERIAL
FILLER COKE

CARBON WHISKERS

Description:
See: GRAPHITE WHISKERS

CARBONACEOUS MESOPHASE

Description:
CARBONACEOUS MESOPHASE is a liquid-crystalline state of PITCH which shows the optical birefringence of disc-like (discotic) nematic liquid crystals. It can be formed as an intermediate phase during thermolysis (pyrolysis) of an isotropic molten PITCH or by precipitation from PITCH fractions prepared by selective extraction. Generally, the spherical mesophase precipitated from a pyrolyzing PITCH has the BROOKS AND TAYLOR STRUCTURE. With continuous heat treatment the CARBONACEOUS MESOPHASE coalesces to a state of BULK MESOPHASE before solidification to GREEN COKE with further loss of hydrogen or low-molecular-weight compounds.

See: BROOKS AND TAYLOR STRUCTURE IN THE CARBONACEOUS MESOPHASE
BULK MESOPHASE
GREEN COKE
PITCH

Notes:
In the formation of CARBONACEOUS MESOPHASE by thermolysis (pyrolysis) of isotropic molten PITCH, the development of a liquid-crystalline phase is accompanied by simultaneous aromatic polymerization reactions. The reactivity of PITCH with increasing heat treatment temperature and its thermosetting nature are responsible for the lack of a true reversible thermotropic phase transition for the BULK MESOPHASE in most PITCHES. Due to its glass-like nature most of the liquid-crystalline characteristics are retained in the super-cooled solid state.

See: BROOKS AND TAYLOR STRUCTURE IN THE CARBONACEOUS MESOPHASE
BULK MESOPHASE
PITCH

CARBONIZATION

Description:

CARBONIZATION is a process by which solid residues with increasing content of the element carbon are formed from organic material usually by pyrolysis in an inert atmosphere.

Notes:

As with all pyrolytic reactions, CARBONIZATION is a complex process in which many reactions take place concurrently such as dehydrogenation, condensation, hydrogentransfer and isomerization. It differs from COALIFICATION in that its reaction rate is faster by many orders of magnitude. The final pyrolysis temperature applied controls the degree of CARBONIZATION and the residual content of foreign elements, *e.g.* at $T \sim 1200$ K the carbon content of the residue exceeds a mass fraction of 90 wt.%, whereas at $T \sim 1600$ K more than 99 wt.% carbon is found.

See: CALCINED COKE
COALIFICATION

CATALYTIC GRAPHITIZATION

Description:

CATALYTIC GRAPHITIZATION refers to a transformation of NON-GRAPHITIC CARBON into GRAPHITE by heat treatment in the presence of certain metals or minerals.

See: GRAPHITE
GRAPHITIZATION
NON-GRAPHITIC CARBON

Notes:

CATALYTIC GRAPHITIZATION gives a fixed degree of GRAPHITIZATION at lower temperature and/or for a shorter heat treatment time than in the absence of the catalytic additives (or a higher degree of GRAPHITIZATION at fixed heat treatment conditions). Often it involves dissolution of CARBON and precipitation of GRAPHITE at the catalyst particles so that NON-GRAPHITIZING CARBONS can be graphitized by this procedure.

See: CARBON
GRAPHITE
GRAPHITIZATION
NON-GRAPHITIZING CARBON

CHAR

Description:

CHAR is a solid decompostion product of a natural or synthetic organic material.

Notes:

If the precursor has not passed through a fluid stage, CHAR will retain the characteristic shape of the precursor (although becoming of smaller size). For such materials the term "pseudomorphous" has been used. Some simple organic compounds, *e.g.* sugar, melt at an early stage of decomposition and then polymerize during CARBONIZATION to produce CHARS.

See: CARBONIZATION

CHARCOAL

Description:

CHARCOAL is a traditional term for a CHAR obtained from wood, peat, coal or some related natural organic materials.

See: CHAR

Note:

CHARCOAL has highly reactive inner surfaces and a low sulfur content. It has or has had, therefore, a variety of uses, *e.g.* in ferrous metallurgy and for gun-powder (minor uses: medical purpose and paint materials).

COAL-DERIVED PITCH COKE

Description:

COAL-DERIVED PITCH COKE is the primary industrial solid CARBONIZATION product obtained from COAL TAR PITCH, and is mainly produced in chamber or DELAYED COKING PROCESSES.

See: CARBONIZATION
COAL TAR PITCH
DELAYED COKING PROCESS

Note:

COAL-DERIVED PITCH COKE, although it exhibits a pregraphitic microstructure, has often a lower graphitizability than PETROLEUM COKE. Fractions of COAL TAR PITCHES (obtained by extraction or filtration) may form COKES with needle-like structures and have an improved graphitizability. The usually lower graphitizability compared to PETROLEUM COKE is due to an inhibition of mesophase growth because of chemical and physical differences of the cokes.

See: COAL TAR PITCHES
COKE
PETROLEUM COKE

COAL TAR PITCH

Description:

COAL TAR PITCH is a residue produced by distillation or heat treatment of coal tar. It is a solid at room temperature, consists of a complex mixture of numerous predominantly aromatic hydrocarbons and heterocyclics, and exhibits a broad softening range instead of a defined melting temperature.

Note:

The hydrogen aromaticity in COAL TAR PITCH (ratio of aromatic to total content of hydrogen atoms) varies from 0.7 to 0.9.

COALIFICATION

Description:

COALIFICATION is a geological process of formation of materials with increasing content of the element carbon from organic materials that occurs in a first, biological stage into peats, followed by a gradual transformation into coal by action of moderate temperature (about 500 K) and high pressure in a geochemical stage.

Notes:

COALIFICATION is a dehydrogenation process with a reaction rate slower by many orders of magnitude than that of CARBONIZATION. Some specific reactions approach completion before others have started. The dehydrogenation remains incomplete. The degree of COALIFICATION reached by an organic material in the process of COALIFICATION increases progressively and can be defined by means of the measured C/H ratio and of the residual contents of oxygen, sulfur and nitrogen.

See: CARBONIZATION

COKE

Description:

COKE is a solid high in content of the element carbon and structurally in the NON-GRAPHITIC state. It is produced by pyrolysis of organic material which has passed, at least in part, through a liquid or liquid-crystalline state during the CARBONIZATION process. COKE can contain mineral matter.

See: CARBONIZATION
NON-GRAPHITIC CARBON

Notes:
As some parts, at least, of the CARBONIZATION product have passed through a liquid or liquid-crystalline state, the resulting NON-GRAPHITIC CARBON is of the graphitizable variety. From a structural viewpoint, the term COKE characterizes the state of GRAPHITIZABLE CARBON before the beginning of GRAPHITIZATION.
See: CARBONIZATION
GRAPHITIZABLE CARBON
GRAPHITIZATION
NON-GRAPHITIC CARBON

COKE BREEZE
Description:
COKE BREEZE is a by-product of COKE manufacture; it is the residue from the screening of heat-treated COKE; the particle size is less than 10 mm. Generally, COKE BREEZE has a volatile matter content of <3 wt.%.
See: COKE

COLLOIDAL CARBON
Description:
COLLOIDAL CARBON is a PARTICULATE CARBON with particle sizes below *ca.* 1000 nm in at least one dimension.
See: PARTICULATE CARBON

Note:
COLLOIDAL CARBON exists in several morphologically distinct forms.
See: PARTICULATE CARBON
CARBON BLACK

DELAYED COKE
Description:
DELAYED COKE is a commonly used term for a primary CARBONIZATION product (GREEN or RAW COKE) from high-boiling hydrocarbon fractions (heavy residues of petroleum or coal processing) produced by the DELAYED COKING PROCESS.
See: CARBONIZATION
DELAYED COKING PROCESS
GREEN or RAW COKE

Notes:
DELAYED COKE has, with only a few exceptions, a better graphitizability than COKES produced by other coking processes even if the same feedstock is used. DELAYED COKE contains a mass fraction of volatile matter between 4 and 15 wt.% which can be released during heat treatment.
See: COKE
DELAYED COKING PROCESS

DELAYED COKING PROCESS
Description:
DELAYED COKING PROCESS is a thermal process which increases the molecular aggregation or association in petroleum-based residues or COAL TAR PITCHES leading to extended mesophase domains. This is achieved by holding them at an elevated temperature (usually 750 K - 765 K) over a period of time (12 to 36 hours). It is performed in a coking drum and is designed to ultimately produce DELAYED COKE. The feed is rapidly preheated in a tubular furnace to about 760 K.
See: COAL TAR PITCH
DELAYED COKE

Notes:
NEEDLE COKE is the premium product of the DELAYED COKING PROCESS. It is generally produced from highly aromatic residues from, for instance, the steam cracking of gas oil. Its appearance and preferred orientation of the GRAPHENE LAYERS is the consequence of the evolved gaseous products percolating through the mesophase which must not have too high a viscosity. A close control of temperature , time, and feedstock is essential. Lower grades, for instance ISOTROPIC COKES, are used for CARBON ELECTRODES applied, for example, in the production of aluminium.
See: ISOTROPIC CARBON
NEEDLE COKE

DIAMOND
Description:
DIAMOND is an allotropic form of the element carbon with cubic structure (space group Oh^7 - $Fd3m$) which is thermodynamically stable at pressures above 6 GPa at room temperature and metastable at atmospheric pressure. At low pressures DIAMOND converts rapidly to GRAPHITE at temperatures above 1900 K in an inert atmosphere. The chemical bonding between the carbon atoms is covalent with sp^3 hybridization.
See: CARBON
GRAPHITE

Note:
There is also a hexagonal diamond-like structure of the element CARBON (Lonsdaleite).
See: CARBON

DIAMOND BY CVD
Description:
DIAMOND BY CVD (Chemical Vapour Deposition) is formed as crystals or as films from various gaseous hydrocarbons or other organic molecules in the presence of activated, atomic hydrogen. It consists of sp^3-hybridized carbon atoms with the three-dimensional crystalline structure of the diamond lattice.
See: DIAMOND-LIKE CARBON FILMS

Notes:
"CVD diamond" or "low-pressure diamond" are synonyms of the term DIAMOND BY CVD. DIAMOND BY CVD can be prepared in a variety of ways. Deposition parameters are: total (low) pressure, partial hydrogen pressure, precursor molecules in the gas phase, temperature for activation of the hydrogen and that of the surface of the underlying substrate. The energy supply for the hydrogen activation may be, for instance: heat, radio frequency, microwave excitation (plasma deposition) or accelerated ions (*e.g.* Ar^+ ions). CVD diamond has also been obtained at atmospheric pressure from oxyacetylene torches and by other flame-based methods.
Often CVD carbon films consist of a mixture of sp^2- und sp^3-hybridized carbon atoms and do not have the three-dimensional structure of the DIAMOND lattice. In this case they should be called HARD AMORPHOUS CARBON or DIAMOND-LIKE CARBON FILMS.
See: DIAMOND-LIKE CARBON FILMS

DIAMOND-LIKE CARBON FILMS
Description:
DIAMOND-LIKE CARBON (DLC) FILMS are hard, amorphous films with a significant fraction of sp^3-hybridized carbon atoms and which can contain a significant amount of hydrogen. Depending on the deposition conditions, these films can be fully amorphous or contain DIAMOND crystallites. These materials are not called DIAMOND unless a full three-dimensional crystalline lattice of DIAMOND is proven.
See: DIAMOND

Notes:
Diamond-like films without hydrogen can be prepared by carbon ion beam deposition, ion-assisted sputtering from GRAPHITE or by laser ablation of GRAPHITE. DIAMOND-LIKE CARBON FILMS containing significant contents of hydrogen are prepared by chemical vapour deposition. The hydrogen content is usually over 25 atomic %. The deposition parameters are (low) total pressure, hydrogen partial pressure, precursor molecules, and plasma ionisation. The plasma activation can be radio frequency, microwave, or Ar^+ ions. High ionisation favours amorphous films while high atomic hydrogen contents favour DIAMOND crystallite formation. Because of the confusion about structure engendered by the term DIAMOND-LIKE CARBON FILMS, the term HARD AMORPHOUS CARBON has been suggested as a synonym.

ELECTROGRAPHITE
Description:
ELECTROGRAPHITE is a SYNTHETIC GRAPHITE made by electrical heating of GRAPHITIZABLE CARBON.
See: SYNTHETIC GRAPHITE

EXFOLIATED GRAPHITE
Description:
EXFOLIATED GRAPHITE is the product of very rapid heating (or flash heating) of graphite intercalation compounds, such as graphite hydrogen sulfate of relatively large particle diameter (flakes). The vaporizing intercalated substances force the graphite layers apart. The EXFOLIATED GRAPHITE assumes an accordion-like shape with an apparent volume often hundreds of times that of the original graphite flakes.

Notes:
EXFOLIATED GRAPHITE is usually prepared from well-crystallized NATURAL flake GRAPHITE. It is used for the production of graphite foils. EXFOLIATED GRAPHITE is different from the deflagration product of graphite oxide (graphitic acid).
See: NATURAL GRAPHITE

FIBROUS ACTIVATED CARBON
Description:
FIBROUS ACTIVATED CARBON is an ACTIVATED CARBON in the form of fibres, filaments, yarns or rovings and fabrics or felts. Such fibers differ from CARBON FIBRES used for reinforcement purposes in composites by their high surface area, high porosity and low mechanical strength.
See: ACTIVATED CARBON
CARBON FIBRES

Note:
Sometimes fabrics of FIBROUS ACTIVATED CARBON are named CHARCOAL cloths; a more precise term is "activated carbon cloth".
See: ACTIVATED CHARCOAL
CHARCOAL

FIBROUS CARBON
Description:
See: FILAMENTOUS CARBON

FILAMENTOUS CARBON
Description:
FILAMENTOUS CARBON is a carbonaceous deposit from gaseous carbon compounds, consisting of filaments grown by the catalytic action of metal particles.

Notes:
In general, such deposits are obtained at pressures of <100 kPa in the temperature region 600 K to 1300 K on metals such as iron, cobalt or nickel.
Typical filaments consist of a duplex structure, a relatively oxidation-resistant skin surrounding a more easily oxidizable core, with a metal particle located at the growing end of the filament. They generally range from 0.01 to 0.5 μm in diameter and up to 10 μm in length.
In some systems, the metal particles are located in the middle of the filaments, and there are also examples where several filaments originate from a single particle.
The filaments may be produced in different conformations, such as helical, twisted and straight.
See: R.T.K.Baker and P.S.Harris, in: *Chemistry and Physics of Carbon*, Vol.14, edited by P.L.Walker, Jr. and P.A.Thrower, Marcel Dekker, New York, 1978, pp. 83-165.

FILLER
Description:
FILLER (also called GRIST) is a petroleum- or coal-based coke fraction of a green, carbon mix or formulation. Coarse particles, >0.425 mm, are sometimes referred to as tailings; fine particles, <0.074 mm, are referred to as flour. GRAPHITE flour is also used as a filler.

FILLER COKE
Description:
FILLER COKE is the main constituent of a carbon artifact, introduced as solid component (predominantly in the form of PARTICULATE CARBON) into the "CARBON MIX" from which POLYGRANULAR CARBON and GRAPHITE materials are obtained by heat treatment.
See: CARBON MATERIAL
CARBON MIX
GRAPHITE MATERIAL
PARTICULATE CARBON
POLYGRANULAR CARBON
POLYGRANULAR GRAPHITE

Note:
FILLER COKE is not necessarily the only, but it is commonly the most important FILLER material used in a "CARBON MIX" which consists of FILLER and binder.
See: CARBON MIX
FILLER

FLUID COKE
Description:
FLUID COKE is the CARBONIZATION product of high-boiling hydrocarbon fractions (heavy residues of petroleum or coal processing) produced by the fluid coking process.
See: CARBONIZATION

Notes:
FLUID COKE consists of spherulitic grains with a spherical layer structure and is generally less graphitizable than DELAYED COKE. Therefore, it is not suitable as FILLER COKE for POLYGRANULAR GRAPHITE products and is also less suitable for POLYCRYSTALLINE CARBON products. Because of its isotropy it is less suitable to produce an anisotropic SYNTHETIC GRAPHITE. All COKES contain a fraction of matter that can be released as volatiles during heat treatment. This mass fraction, the so-called volatile matter, is in the case of FLUID COKE about 6 wt.%.
See: COKE
DELAYED COKE
FILLER COKE
POLYGRANULAR GRAPHITE

cont.

POLYCRYSTALLINE CARBON
SYNTHETIC GRAPHITE

FULLERENES
See: Note to the preface.

FURNACE BLACK
Description:
FURNACE BLACK is a type of CARBON that is produced industrially in a furnace by incomplete combustion in an adjustable and controllable process that yields a wide variety of properties within the product.
See: CARBON BLACK

Note:
The most widely employed industrial process for CARBON BLACK production is the furnace process.
See: CARBON BLACK

GAS PHASE-GROWN CARBON FIBRES
Description:
GAS-PHASE-GROWN CARBON FIBRES are CARBON FIBRES grown in an atmosphere of hydrocarbons with the aid of fine particulate solid catalysts such as iron or other transition metals and consisting of GRAPHITIZABLE CARBON.
See: CARBON FIBRES
GRAPHITIZABLE CARBON

Notes:
GAS PHASE-GROWN CARBON FIBRES transform during GRAPHITIZATION HEAT TREATMENT into GRAPHITE FIBRES. These show a very high degree of preferred orientation and are particularly suitable for intercalation treatments. The term "vapour-grown carbon fibres" alternatively used in the literature is acceptable. The use of the term "CVD fibres" is not recommended as an alternative for GAS PHASE-GROWN CARBON FIBRES since the term "CVD fibres" also describes fibres grown by a chemical vapour deposition (CVD) process on substrate fibres.
See: GRAPHITE FIBRES
GRAPHITIZATION HEAT TREATMENT

GLASS-LIKE CARBON
Description:
GLASS-LIKE CARBON is an AGRANULAR NON-GRAPHITIZABLE CARBON with a very high isotropy of its structural and physical properties and with a very low permeability for liquids and gases. The original surfaces and the fracture surfaces have a pseudo-glassy appearance.
See: AGRANULAR CARBON
NON-GRAPHITIZABLE CARBON

Note:
The often used synonyms "Glassy Carbon" and "Vitreous Carbon" have been introduced as trademarks and should not be used as terms. From a scientific viewpoint, all synonymous terms suggest a similiarity with the structure of silicate glasses which does not exist in GLASS-LIKE CARBON, except for the pseudo-glassy appearance of the surface.

GLASS-LIKE CARBON cannot be described as AMORPHOUS CARBON because it consists of two-dimensional structural elements and does not exhibit "dangling" bonds.
See: AMORPHOUS CARBON

GRANULAR CARBON

Description:

The term GRANULAR CARBON is equivalent to coarse PARTICULATE CARBON. This is a CARBON MATERIAL consisting of separate particles or grains which are monolithic, on the average larger than about 100 μm in diameter, but smaller than about 1 cm.

See: CARBON MATERIAL
PARTICULATE CARBON

Notes:

Although limits of size cannot be exactly defined, coke grains obtained by grinding belong to coarse PARTICULATE CARBON for grain sizes above *ca.* 100 μm, or to fine PARTICULATE CARBON for grain sizes below *ca.* 100 μm. COLLOIDAL GRAPHITE obtained by grinding of NATURAL GRAPHITE is a typical extra fine PARTICULATE CARBON. Industrial CARBON MATERIALS (such as electrodes) are made with FILLERS composed of coarse PARTICULATE CARBON (coke grains) and fine PARTICULATE CARBON (flour), and sometimes even COLLOIDAL CARBON (CARBON BLACKS or SOOT). They are therefore polygranular materials.

See: CARBON BLACK
CARBON MATERIAL
COLLOIDAL CARBON
FILLER
NATURAL GRAPHITE
PARTICULATE CARBON
SOOT

GRAPHENE LAYER

Description:

GRAPHENE is a single carbon layer of the graphite structure, describing its nature by analogy to a polycyclic aromatic hydrocarbon of quasi infinite size.

Notes:

Previously, descriptions such as graphite layers, carbon layers or carbon sheets have been used for the term GRAPHENE.

Because GRAPHITE designates that modification of the chemical element CARBON, in which planar sheets of carbon atoms, each atom bound to three neighbours in a honeycomb-like structure, are stacked in a three-dimensional regular order, it is not correct to use for a single layer a term which includes the term GRAPHITE, which would imply a three-dimensional structure. The term GRAPHENE should be used only when the reactions, structural relations or other properties of individual layers are discussed.

See: CARBON
GRAPHITE

GRAPHITE

Description:

GRAPHITE is an allotropic form of the element carbon consisting of layers of hexagonally arranged carbon atoms in a planar condensed ring system (GRAPHENE LAYERS). The layers are stacked parallel to each other in a three-dimensional crystalline long-range order. There are two allotropic forms with different stacking arrangements, hexagonal and rhombohedral. The chemical bonds within the layers are covalent with sp^2 hybridization and with a C-C-distance of 141.7 pm. The weak bonds between the layers are metallic with a strength comparable to VAN DER WAALS bonding only.

See: CARBON
HEXAGONAL GRAPHITE
RHOMBOHEDRAL GRAPHITE

Note:

The term GRAPHITE is also used often but incorrectly to describe GRAPHITE MATERIALS, *i.e.* materials consisting of GRAPHITIC CARBON made from CARBON MATERIALS by processing to temperatures greater than 2500 K, even though no perfect graphite structure is present.

See: GRAPHITIC CARBON
CARBON MATERIAL
GRAPHITE MATERIAL

GRAPHITE ELECTRODE

Description:

See: CARBON ELECTRODE

GRAPHITE FIBRES

Description:

GRAPHITE FIBRES are CARBON FIBRES consisting mostly of SYNTHETIC GRAPHITE for which three-dimensional crystalline order is confirmed by X-ray diffraction.

See: CARBON FIBRES
SYNTHETIC GRAPHITE

Note:

GRAPHITE FIBRES can be obtained by GRAPHITIZATION HEAT TREATMENT of CARBON FIBRES if these consist mostly of GRAPHITIZABLE CARBON. If the *h,k,l* diffraction lines are difficult to recognize because they are of minor intensitiy, the mean interlayer spacing $c/2$ can be used as indication for the presence of a graphitic structure. The $c/2$ value of 0.34 nm is generally considered as an upper limit for SYNTHETIC GRAPHITE.

See: CARBON FIBRES
GRAPHITIZABLE CARBON
GRAPHITIZATION HEAT TREATMENT
SYNTHETIC GRAPHITE

GRAPHITE MATERIAL

Description:

GRAPHITE MATERIAL is a material consisting essentially of GRAPHITIC CARBON.

See: GRAPHITE
GRAPHITIC CARBON

Note:

The use of the term GRAPHITE as a short term for material consisting of GRAPHITIC CARBON is incorrect. The term GRAPHITE can only be used in combination with other nouns or clarifying adjectives for special types of GRAPHITE MATERIALS (graphite electrodes, NATURAL GRAPHITE and others). The use of the term GRAPHITE without a noun or clarifying adjective should be restricted to the allotropic form of the element CARBON:

See: CARBON
GRAPHITE
GRAPHITIC CARBON
NATURAL GRAPHITE

GRAPHITE WHISKER

Description:

GRAPHITE WHISKERS consist of thin, approximately cylindrical filaments in which GRAPHENE LAYERS are arranged in a scroll-like manner. There is, at least in part, a regular stacking of the layers as in the GRAPHITE lattice, giving rise to *h,k,l,* X-ray reflections. The physical properties of GRAPHITE WHISKERS approach, along the cylinder axis, those of GRAPHITE.

Note:

If there is, due to misalignment of the layers caused by their bending, no three-dimensional stacking order as in GRAPHITE, the term CARBON WHISKERS should be used. GRAPHITE

WHISKERS and CARBON WHISKERS should be distinguished from more disordered FILAMENTIOUS CARBON.

See: FILAMENTOUS CARBON
GRAPHITIC CARBON

GRAPHITIC CARBON

Description:

GRAPHITIC CARBONS are all varieties of substances consisting of the element carbon in the allotropic form of GRAPHITE irrespective of the presence of structural defects.

See: GRAPHITE

Note:

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

See: NON-GRAPHITIC CARBON

GRAPHITIZABLE CARBON

Description:

GRAPHITIZABLE CARBON is a NON-GRAPHITIC CARBON which upon GRAPHITIZATION HEAT TREATMENT converts into GRAPHITIC CARBON.

See: GRAPHITIC CARBON
GRAPHITIZATION HEAT TREATMENT
NON-GRAPHITIC CARBON

Note:

If it is preferred to define the characterizable state of material instead of its behaviour during subsequent treatment, the term "Pregraphitic Carbon" could be considered.

GRAPHITIZATION

Description:

GRAPHITIZATION is a solid-state transformation of thermydynamically unstable NON-GRAPHITIC CARBON into GRAPHITE by means of heat treatment.

See: GRAPHITE
NON-GRAPHITIC CARBON

Note:

GRAPHITIZATION is also used for the transformation of metastable DIAMOND into GRAPHITE by heat treatment, as well as in metallurgy for the formation of GRAPHITE from thermodynamically unstable carbides by thermal decomposition at high temperatures. Such uses of the term GRAPHITIZATION are in line with the above definition. The use of the term GRAPHITIZATION to indicate a process of thermal treatment of CARBON MATERIALS at $T > 2500$ K regardless of any resultant crystallinity is incorrect.

See: CARBON MATERIALS
DIAMOND
GRAPHITE
GRAPHITIZATION
GRAPHITIZATION HEAT TREATMENT

GRAPHITIZATION HEAT TREATMENT

Description:

GRAPHITIZATION HEAT TREATMENT is a process of heat treatment of a NON-GRAPHITIC CARBON, industrially performed at temperatures in the range between 2500 K and 3300 K, to achieve transformation into GRAPHITIC CARBON.

See: GRAPHITIC CARBON
GRAPHITIZATION
NON-GRAPHITIC CARBON

Note:
The term GRAPHITIZATION HEAT TREATMENT does not include information as to the crystallinity achieved by the heat treatment, that is the extent of transformation into GRAPHITIC CARBON or the degree of GRAPHITIZATION. Only for such a transformation into GRAPHITIC CARBON should the term GRAPHITIZATION be used. Consequently: the common use of the term GRAPHITIZATION for the heat treatment process only, regardless of the resultant crystallinity, is incorrect and should be avoided.
See: GRAPHITIC CARBON
GRAPHITIZATION

GRAPHITIZED CARBON
Description:
GRAPHITIZED CARBON is a GRAPHITIC CARBON with more or less perfect three-dimensional hexagonal crystalline order prepared from NON-GRAPHITIC CARBON by GRAPHITIZATION HEAT TREATMENT:
See: GRAPHITIC CARBON
GRAPHITIZATION HEAT TREATMENT
NON-GRAPHITIC CARBON

Note:
NON-GRAPHITIZABLE CARBONS do not transform into GRAPHITIC CARBON on heat treatment at temperatures above 2500 K and therefore are not GRAPHITIZED CARBONS.
See: GRAPHITIZABLE CARBON
NON-GRAPHITIZABLE CARBON

GREEN COKE
Description:
GREEN COKE (RAW COKE) is the primary solid CARBONIZATION product from high boiling hydrocarbon fractions obtained at temperatures below 900 K. It contains a fraction of matter that can be released as volatiles during subsequent heat treatment at temperatures up to approximately 1600 K. This mass fraction, the so-called volatile matter, is in the case of GREEN COKE between 4 and 15 wt.%, but it depends also on the heating rate.
See: CARBONIZATION
RAW COKE

Note:
RAW COKE is an equivalent term to GREEN COKE although it is now less frequently used. The so-called volatile matter of GREEN COKE depends on temperature and time of coking, but also on the method for its determination.
See: RAW COKE

HARD AMORPHOUS CARBON FILMS
Description:
HARD AMORPHOUS CARBON FILMS is a synonym for DIAMOND-LIKE CARBON FILMS.
See: DIAMOND-LIKE CARBON FILMS.

HEXAGONAL GRAPHITE
Description:
HEXAGONAL GRAPHITE is the thermodynamically stable form of GRAPHITE with an ABAB stacking sequence of the GRAPHENE LAYERS. The exact crystallographic description of this allotropic form is given by the space group $D6h^4$ - $P6_3/mmc$ (unit cell constants: a = 245.6 pm, c = 670.8 pm). HEXAGONAL GRAPHITE is thermodynamically stable below approximately 2600 K and 6 GPa.
See: GRAPHITE

Note:
The use of the term GRAPHITE instead of the more exact term HEXAGONAL GRAPHITE may be tolerated in view of the minor importance of RHOMBOHEDRAL GRAPHITE, the other allotropic form.
See: GRAPHITE
RHOMBOHEDRAL GRAPHITE

HIGH-PRESSURE GRAPHITIZATION
Description:
HIGH-PRESSURE GRAPHITIZATION refers to a solid-state transformation of NON-GRAPHITIC CARBON into GRAPHITE by heat treatment under elevated pressure (*e.g.* 100 to 1000 MPa) so that a definitely higher degree of GRAPHITIZATION is achieved at lower temperature and/or for a shorter heat treatment time than in heat treatment of the same NON-GRAPHITIC material at atmospheric pressure.
See: GRAPHITE
GRAPHITIZATION
NON-GRAPHITIC CARBON

HIGHLY ORIENTED PYROLYTIC GRAPHITE
Description:
HIGHLY ORIENTED PYROLYTIC GARPHITE (HOPG) is a PYROLYTIC GRAPHITE with an angular spread of the *c*-axes of the crystallites of less than 1 degree.
See: GRAPHITE
PYROLYTIC GRAPHTE

Note:
Commercial HIGHLY ORIENTED PYROLYTIC GRAPHITE is usually produced by stress annealing at approximately 3300 K.

ISOTROPIC CARBON
Description:
ISOTROPIC CARBON is a monolithic CARBON MATERIAL without preferred crystallographic orientation of the microstructure.
See: CARBON MATERIAL

Note:
ISOTROPIC CARBON can also be a GRAPHITE MATERIAL. The isotropy can be gross (bulk), macroscopic, or microscopic, depending on the structural level at which isotropy is obtained. This word is widely used today and its meaning covers all the above levels. For example, the aerospace graphites have isotropy built in by random grain orientation. Some NUCLEAR GRAPHITES are isotropic at the crystalline (sub-grain) level.
See: GRAPHITE MATERIAL
NUCLEAR GRAPHITE

ISOTROPIC PITCH-BASED CARBON FIBRES
Description:
ISOTROPIC PITCH-BASED CARBON FIBRES are CARBON FIBRES obtained by CARBONIZATION of isotropic pitch fibres after these have been stabilized (*i.e.*, made non-fusible).
See: CARBON FIBRES
CARBONIZATION
PITCH-BASED CARBON FIBRES
STABILIZATION TREATMENT

Notes:
During fabrication of ISOTROPIC PITCH-BASED CARBON FIBRES no means (neither mechanical nor chemical) are applied to achieve preferred orientation of the polyaromatic molecules in the fibre direction. They belong to the CARBON FIBRES TYPE LM (Low Modu-

lus), and because of the relatively low values of strength and Young's modulus this PITCH-BASED CARBON FIBRE type is not used for high-performance reinforcement purposes.

See: CARBON FIBRES TYPE LM
PITCH-BASED CARBON FIBRES

LAMP BLACK

Description:

LAMP BLACK is a special type of CARBON BLACK produced by incomplete combustion of a fuel rich in aromatics that is burned in flat pans. LAMP BLACK is characterized by a relatively broad particle size distribution.

See: CARBON BLACK

MESOGENIC PITCH

Description:

MESOGENIC PITCH is a PITCH with a complex mixture of numerous essentially aromatic hydrocarbons. It does not contain anisotropic particles detectable by optical microscopy. MESOGENIC PITCH is low in quinoline-insoluble fractions and capable of transforming into MESOPHASE PITCH during continuous heat treatment above 750 K by the formation of optically detectable CARBONACEOUS MESOPHASE.

See: CARBONACEOUS MESOPHASE
MESOPHASE PITCH
PITCH

MESOPHASE PITCH

Description:

MESOPHASE PITCH is a PITCH with a complex mixture of numerous essentially aromatic hydrocarbons containing anisotropic liquid-crystalline particles (CARBONACEOUS MESOPHASE) detectable by optical microscopy and capable of coalescence into the BULK MESOPHASE.

See: BULK MESOPHASE
CARBONACEOUS MESOPHASE
MESOGENIC PITCH
PITCH

Notes:

The CARBONACEOUS MESOPHASE particles are formed from the aromatics of high molecular mass in MESOGENIC PITCH, which have not yet been aggregated to particles detectable by optical microscopy within the apparently isotropic PITCH matrix. The CARBONACEOUS MESOPHASE is insoluble in quinoline and pyridine, but the amount of mesophase measured from microscopical observation appears somewhat higher because parts of the CARBONACEOUS MESOPHASE can be extracted by the solvents.

See: CARBONACEOUS MESOPHASE
MESOGENIC PITCH
PITCH

MESOPHASE PITCH-BASED CARBON FIBRES

Description:

MESOPHASE PITCH-BASED CARBON FIBRES (MPP-BASED CARBON FIBRES) are CARBON FIBRES obtained from MESOGENIC PITCH after it has been transformed into MESOPHASE PITCH (MPP) at least during the process of spinning, and after the spun MESOPHASE PITCH fibres have been made non-fusible (stabilized) and carbonized.

See: CARBON FIBRES
MESOGENIC PITCH
MESOPHASE PITCH
PITCH
PITCH-BASED CARBON FIBRES

METALLURGICAL COKE

Description:

METALLURGICAL COKE is produced by CARBONIZATION of coals or coal blends at temperatures up to 1400 K to produce a macroporous CARBON MATERIAL of high strength and relatively large lump size.

See: CARBON MATERIAL
CARBONIZATION

Notes:

METALLURGICAL COKES must have a high strength to support heavy loads in the blast furnace without disintegration. METALLURGICAL COKE is also used as FILLER COKE for POLYGRANULAR CARBON products.

See: FILLER COKE
POLYGRANULAR CARBON

MICROPOROUS CARBON

Description:

MICROPOROUS CARBON is a porous CARBON MATERIAL, usually a CHAR or CARBON FIBRES, which may or may not have been subjected to an activation process to increase its adsorptive properties. A MICROPOROUS CARBON is considered to have a major part of its porosity in pores of less than 2 nm width and to exhibit apparent surface areas usually higher than 200 to 300 $m^2 \cdot g^{-1}$.

See: ACTIVATED CARBON
FIBRIOUS ACTIVATED CARBON

Notes:

For definition of micropores see: IUPAC Manual of Symbols and Terminology, Appendix 2, Pt.1, Colloid and Surface Chemistry. *Pure Appl.Chem.* **31**, 518 (1972).

The surface areas determined by the Brunauer-Emmett-Teller (BET) method are apparent surface areas only since the BET adsorption equation is, in principle, not valid when micropore filling occurs. The determination of the true surface area in the micropores depends on the method used for the evaluation of the adsorption isotherms and on the model used for the shape of the micropores (cylindrical, slit-shaped or other).

MPP-BASED CARBON FIBRES

Description:

See: MESOPHASE PITCH-BASED CARBON FIBRES

NATURAL GRAPHITE

Description:

NATURAL GRAPHITE is a mineral found in nature. It consists of GRAPHITIC CARBON regardless of its crystalline perfection.

See: GRAPHITIC CARBON

Notes:

Some NATURAL GRAPHITES, often in the form of large flakes, show very high crystalline perfection. Occasionally, they occur as single crystals of GRAPHITE. The use of the term NATURAL GRAPHITE as a synonym for the term "Graphite Single Crystal" is incorrect and should be avoided. Varieties of NATURAL GRAPHITE with lower structural perfection are classified as "Microcrystalline NATURAL GRAPHITE". Commercial NATURAL GRAPHITE is often contaminated with other minerals, *e.g.* silicates, and may contain RHOMBOHEDRAL GRAPHITE due to intensive milling.

See: GRAPHITE
RHOMBOHEDRAL GRAPHITE

NEEDLE COKE

Description:

NEEDLE COKE is the commonly used term for a special type of COKE with extremely high graphitizability resulting from a strong preferred parallel orientation of its turbostratic layer structure and a particular physical shape of the grains.

See: COKE

Notes:

NEEDLE COKE is derived mainly from clean (*i.e.* lacking hetero atoms and solids) and highly aromatic (*i.e.* several condensed rings per cluster) feedstocks with a very low concentration of insolubles. Upon solidification a material with a distinctive streaked or flow-like macroscopic appearance is produced. Upon grinding the COKE breaks up first into macroscopic needles and then, after further grinding, into microplatelets. Sometimes the word "acicular" is used as a synonym for needle-like.

See: COKE
DELAYED COKING PROCESS

NON-GRAPHITIC CARBON

Description:

NON-GRAPHITIC CARBONS are all varieties of solids consisting mainly of the element carbon with two-dimensional long-range order of the carbon atoms in planar hexgonal networks, but without any measurable crystallographic order in the third direction (*c*-direction) apart from more or less parallel stacking.

See: AMORPHOUS CARBON

Note:

Some varieties of NON-GRAPHITIC CARBON convert on heat treatment to GRAPHITIC CARBON (GRAPHITIZABLE CARBON) but some others do not (NON-GRAPHITIZABLE CARBON).

See: GRAPHITIC CARBON
GRAPHITIZABLE CARBON
NON-GRAPHITIC CARBON
NON-GRAPHITIZABLE CARBON

NON-GRAPHITIZABLE CARBON

Description:

NON-GRAPHITIZABLE CARBON is a NON-GRAPHITIC CARBON which cannot be transformed into GRAPHITIC CARBON solely by high-temperature treatment up to 3300 K under atmospheric pressure or lower pressure.

See: GRAPHITIC CARBON
GRAPHITIZATION HEAT TREATMENT
NON-GRAPHITIC CARBON

Note:

The term NON-GRAPHITIZABLE is limited to the result of heat treatment without additional influence of foreign matter or neutron radiation. NON-GRAPHITIZABLE CARBON can be transformed into GRAPHITIC CARBON by a high-temperature process via intermediate dissolution in foreign matter and precipitation under high pressure or by radiation damage.

See: GRAPHITIC CARBON

NUCLEAR GRAPHITE

Description:

NUCLEAR GRAPHITE is a POLYGRANULAR GRAPHITE material for use in nuclear reactor cores consisting of GRAPHITIC CARBON of very high chemical purity. High purity is needed to avoid absorption of low-energy neutrons and the production of undesirable radioactive species.

See: GRAPHITE MATERIAL
GRAPHITIC CARBON
POLYGRANULAR GRAPHITE

Notes:
Apart from the absence of neutron-absorbing impurities, modern reactor graphites are also characterized by a high degree of GRAPHITIZATION and no preferred bulk orientation. Such properties increase the dimensional stability of the NUCLEAR GRAPHITE at high temperatures and in a high flux of neutrons. The term NUCLEAR GRAPHITE is often, but incorrectly, used for any GRAPHITE MATERIAL in a nuclear reactor, even if it serves only for structural purposes.
See: GRAPHITE MATERIAL
GRAPHITIZATION

PAN-BASED CARBON FIBRES
Description:
PAN-PASED CARBON FIBRES are CARBON FIBRES obtained from polyacrylonitrile (PAN) precursor fibres by STABILIZATION TREATMENT, CARBONIZATION, and final heat treatment.
See: CARBON FIBRES
CARBONIZATION
STABILIZATION TREATMENT

PARTICULATE CARBON
Description:
PARTICULATE CARBON is a CARBON MATERIAL consisting of separated monolithic particles.
See: CARBON MATERIAL

Note:
Distinctions should be made between coarse PARTICULATE CARBON or GRANULAR CARBON (larger than about 100 μm, but smaller than about 1 cm in average size), fine PARTICULATE CARBON or powder or flour (between 1 μm and 100 μm in average size) and COLLOIDAL CARBON (below approximately 1 μm in size in at least one direction), *e.g.* CARBON BLACKS and COLLOIDAL CARBON.
See: CARBON BLACK
COLLOIDAL CARBON
GRANULAR CARBON
PARTICULATE CARBON

PETROLEUM COKE
Description:
PETROLEUM COKE is a CARBONIZATION product of high-boiling hydrocarbon fractions obtained in petroleum processing (heavy residues). It is the general term for all special PETROLEUM COKE products such as GREEN, CALCINED and NEEDLE petroleum COKE.
See: CALCINED COKE
CARBONIZATION
GREEN or RAW COKE
NEEDLE COKE

Note:
High-boiling hydrocarbon fractions (heavy residues) used as feedstock for PETROLEUM COKE are residues from distillation (atmospheric pressure, vacuum) or cracking (*e.g.* thermal, catalytic, steam-based) processes. The nature of feedstock has a decisive influence on the graphitizability of the CALCINED COKE.
See: CALCINED COKE

PETROLEUM PITCH
Description:
PETROLEUM PITCH is a residue from heat treatment and distillation of petroleum fractions. It is solid at room temperature, consists of a complex mixture of numerous predominantly

aromatic and alkyl-substituted aromatic hydrocarbons, and exhibits a broad softening range instead of a defined melting temperature.

Note:
The hydrogen aromaticity (ratio of aromatic to total hydrogen atoms) varies between 0.3 and 0.6. The aliphatic hydrogen atoms are typically present in alkyl groups substituted on aromatic rings or as naphthenic hydrogen.

PITCH

Description:
PITCH is a residue from pyrolysis of organic material or tar distillation which is solid at room temperature, consisting of a complex mixture of numerous, essentially aromatic hydrocarbons and heterocyclic compounds. It exhibits a broad softening range instead of a defined melting temperature. When cooled from the melt, pitches solidify without crystallization.

Notes:
The ratio of aromatic to aliphatic hydrogen depends mainly on the source of the starting material. The hydrogen aromaticity (ratio of aromatic to total hydrogen atoms) varies between 0.3 and 0.9.
The aliphatic hydrogen in pitch is largely associated with alkyl side chains substituted on aromatic rings. The content of heterocyclic compounds in pitches varies depending on their origins. Also the softening temperature can vary in a broad range between about 320 K and 570 K depending on the molecular weight (relative molecular mass) and composition of the constituents.

PITCH-BASED CARBON FIBRES

Description:
PITCH-BASED CARBON FIBRES are CARBON FIBRES obtained from PITCH precursor fibres after STABILIZATION TREATMENT, CARBONIZATION, and final heat treatment.
See: CARBON FIBRES
PITCH
STABILIZATION TREATMENT

Notes:
The term PITCH-BASED CARBON FIBRES comprises the ISOTROPIC PITCH-BASED CARBON FIBRES as well as the anisotropic MESOPHASE PITCH-BASED CARBON FIBRES (MPP-BASED CARBON FIBRES). The isotropic type belongs to the CARBON FIBRES TYPE LM (Low Modulus) and is mainly used as filler in polymers and insulation materials and for similar applications. The anisotropic type (MPP-BASED CARBON FIBRES) belongs to the CARBON FIBRES TYPE HM and is used mainly for reinforcement purposes due to its high Young's modulus value.
See: CARBON FIBRES TYPE HM
CARBON FIBRES TYPE LM
ISOTROPIC PITCH-BASED CARBON FIBRES
MESOPHASE PITCH-BASED CARBON FIBRES

POLYCRYSTALLINE GRAPHITE

Description:
POLYCRYSTALLINE GRAPHITE is a GRAPHITE MATERIAL with coherent crytallographic domains of limited size regardless of the perfection and preferred orientation (texture) of their crystalline structure.
See: GRAPHITE MATERIAL

Notes:
The common use of the term POLYCRYSTALLINE GRAPHITE for POLYGRANULAR GRAPHITE is in line with this definition but may be inexact because usually all grains of POLYGRANULAR GRAPHITE are polycrystalline themselves. - POLYCRYSTALLINE

GRAPHITE can exhibit a random orientation, more or less preferred orientation, or a highly oriented texture as in some PYROLYTIC GRAPHITES. There is no sharp transition, however, between the typical polycrystalline texture and the "single crystal-like" texture of HIGHLY ORIENTED PYROLYTIC GRAPHITE (HOPG).

See: HIGHLY ORIENTED PYROLYTIC GRAPHITE
POLYGRANULAR GRAPHITE
PYROLYTIC GRAPHITE

POLYGRANULAR CARBON

Description:
POLYGRANULAR CARBON is a CARBON MATERIAL composed of grains, which can be clearly distinguished by means of optical microscopy.

See: CARBON MATERIAL

Note:
Industrial CARBON MATERIALS (such as electrodes) are mostly polygranular, but special grades are agranular materials, such as GLASS-LIKE CARBON, CARBON FIBRES or PYROLYTIC CARBON. Such materials are covered by the term AGRANULAR CARBON.

See: AGRANULAR CARBON
CARBON FIBRES
CARBON MATERIAL
GLASS-LIKE CARBON
PYROLYTIC CARBON

POLYGRANULAR GRAPHITE

Description:
POLYGRANULAR GRAPHITE is a GRAPHITE MATERIAL composed of grains which can be clearly distinguished by means of optical microscopy.

See: GRAPHITE MATERIAL

Note:
From the viewpoint of crystallinity, a POLYGRANULAR GRAPHITE is always a POLYCRYSTALLINE GRAPHITE, but not *vice versa*. Most industrial GRAPHITE MATERIALS are polygranular. Monogranular materials consist mostly of NON-GRAPHITIC CARBON, such materials are called monolithic or AGRANULAR CARBONS.

See: AGRANULAR CARBON
GRAPHITE MATERIAL
NON-GRAPHITIC CARBON
POLYCRYSTALLINE GRAPHITE

PREMIUM COKE

Description:
PREMIUM COKE is an extremely well graphitizing carbon with a high degree of optical anisotropy (isochromatic areas of optical texture above about 100 μm) and is characterized by a combination of the following properties which differ significantly from those of REGULAR COKE: high real density, low reversible thermal expansion, and low ash content combined, in most cases, with low sulfur content.

See: REGULAR COKE

Note:
PREMIUM COKE is mainly produced from tars or residues from petrochemistry by the DELAYED COKING PROCESS. Also refined COAL TAR PITCHES are used as precursors for PREMIUM COKE production.

See: COAL TAR PITCH
DELAYED COKING PROCESS
REGULAR COKE

PUFFING

Description:

The term PUFFING describes an irreversible expansion of some CARBON ARTIFACTS during GRAPHITIZAION HEAT TREATMENT between 1650 K and 2700 K.

See: CARBON ARTIFACT
COKE
GRAPHITIZATION HEAT TREATMENT

Note:

PUFFING is caused by the release of heteroatoms, for instance sulfur atoms, from the COKE in association with specific microstructural rearrangements.

See: COKE
POLYGRANULAR CARBON
PUFFING INHIBITOR

PUFFING INHIBITOR

Description:

PUFFING INHIBITORS are metals or metal compounds with a high chemical affinity for the heteroatoms in the carbons. They are distributed as fine particles within the CARBON MATERIALS to be graphitized.

See: CARBON MATERIAL

Note:

Iron and iron compounds are most frequently used as PUFFING INHIBITORS when PUFFING is related to sulfur.

See: PUFFING

PYROLYTIC CARBON

Description:

PYROLYTIC CARBON is a CARBON MATERIAL deposited from gaseous hydrocarbon compounds on suitable underlying substrates (CARBON MATERIALS, metals, ceramics) at temperatures ranging from 1000 K to 2500 K (chemical vapour deposition).

See: CARBON MATERIAL

Notes:

A wide range of microstructures, *e.g.* isotropic, lamellar, substrate-nucleated and a varied content of remaining hydrogen, can occur in PYROLYTIC CARBONS, depending on the deposition conditions (temperature, type, concentration and flow rate of the source gas, surface area of the underlying substrate, *etc.*).

"Pyrocarbon" which is synonymous with PYROLYTIC CARBON was introduced as a trademark and should not be used as a term.

The term PYROLYTIC CARBON does not describe the large range of CARBON MATERIALS obtained by thermal degradation (thermolysis, pyrolysis) of organic compounds when they are not formed by chemical vapour deposition (CVD). Also CARBON MATERIALS, obtained by physical vapour deposition (PVD) are not covered by the term PYROLYTIC CARBON.

See: CARBON MATERIAL

PYROLYTIC GRAPHITE

Description:

PYROLYTIC GRAPHITE is a GRAPHITE MATERIAL with a high degree of preferred crystallographic orientation of the *c*-axes perpendicular to the surface of the substrate, obtained by GRAPHITIZATION HEAT TREATMENT of PYROLYTIC CARBON or by chemical vapour deposition at temperatures above 2500 K.

See: GRAPHITE MATERIAL
GRAPHITIZATION HEAT TREATMENT
PYROLYTIC CARBON

Notes:
"Pyrographite", a synonym for PYROLYTIC GRAPHITE, was introduced as a trademark and should not be used as term.
Hot working of PYROLYTIC GRAPHITE (by heat treatment under compressive stress at temperatures above 3000 K) results in HIGHLY ORIENTED PYROLYTIC GRAPHITE (HOPG).
See: HIGHLY ORIENTED PYROLYTIC GRAPHITE

RAW COKE
Description:
See: GREEN COKE

Note:
The term RAW COKE is equivalent to GREEN COKE although it now used less frequently.

RAYON-BASED CARBON FIBRES
Description:
RAYON-BASED CARBON FIBRES are CARBON FIBRES made from rayon (cellulose) precursor fibres.
See: CARBON FIBRES

Notes:
RAYON-BASED CARBON FIBRES have a more isotropic structure than similarly heat-treated polyacrylonitrile (PAN)- or MESOPHASE PITCH (MPP)-BASED CARBON FIBRES. Their Youngs's modulus values are therefore drastically lower ($E^{a)}$ < 100 GPa, $\sigma^{b)}$ > 100 MPa). RAYON-BASED CARBON FIBRES can be transformed into anisotropic CARBON FIRBRES with high strength and Young's modulus values by hot-stretching treatment at temperatures of approximately 2800 K.
See: CARBON FIBRES
PAN-BASED CARBON FIBRS
MESOPHASE PITCH-BASED CARBON FIBRES

[a] *E*, Young's modulus [b] σ, tensile strength

REGULAR COKE
Description:
REGULAR COKE is a PETROLEUM COKE with good graphitizability and is characterized by a combination of properties which differ significantly from those of METALLURGICAL COKE but do not reach the quality level of PREMIUM COKE: These properties are: optical anisotropy, medium reversible thermal expansion, and low ash content.
See: METALLURGICAL COKE
PETROLEUM COKE
PREMIUM COKE

Notes:
Typical characteristics for REGULAR COKE in comparison with those of METALLURGICAL COKE and of PREMIUM COKE calcined at 1620 K are:

		Regular Coke	Premium Coke	Metallurgical Coke
Real density[a]	($g \cdot cm^{-3}$)	2.07 - 2.09	2.12 - 2.14	1.95 - 2.02
CTE[b] (293-773 K)	(K^{-1})	$2.0 \cdot 10^{-6}$	$1.1 \cdot 10^{-6}$	$>3.0 \cdot 10^{-6}$
CTE[b] (293-773 K)	(K^{-1})	$1.0 \cdot 10^{-6}$	$0.5 \cdot 10^{-6}$	$2.0 \cdot 10^{-6}$
Ash	(wt.%)	0.4	0.05	8 - 12
Sulfur	(wt.%)	1.0 - 1.5	0.6	0.6 - 5.0

[a]) measured with *m*-xylene [b]) coefficient of thermal expansion

REGULAR COKE is mainly used for the production of SYNTHETIC CARBON and GRAPHITE MATERIALS.

See: CARBON MATERIAL
GRAPHITE MATERIAL
METALLURGICAL COKE
PREMIUM COKE
SYNTHETIC GRAPHITE

RHOMBOHEDRAL GRAPHITE

Description:

RHOMBOHEDRAL GRAPHITE is a thermodynamically unstable allotropic form of GRAPHITE with an ABCABC stacking sequence of the layers. The exact crystallographic description of this allotropic form is given by the space group D_{3d}^5 - $R\bar{3}m$, (unit cell constants: a = 256.6 pm, c = 1006.2 pm).

See: GRAPHITE

Notes:

The structure of RHOMBOHEDRAL GRAPHITE can be best considered as an extended stacking fault in HEXAGONAL GRAPHITE. RHOMBOHEDRAL GRAPHITE can not be isolated in pure form (NATURAL GRAPHITE and laboratory preparations contain less than 40% of RHOMBOHEDRAL GRAPHITE in combination with HEXAGONAL GRAPHITE). It is produced by shear deformation of HEXAGONAL GRAPHITE and transforms progressively to the hexagonal (ABAB) modification on heating above 1600 K.

See: HEXAGONAL GRAPHITE
NATURAL GRAPHITE

SEMICOKE

Description:

SEMICOKE is a carbonaceous material intermediate between a fusible mesophase pitch and a non-deformable GREEN COKE produced by incomplete CARBONIZATION at temperatures between the onset of fusion (of coal, *ca.* 620 K), and complete devolatilization. SEMICOKE still contains volatile matter, therefore.

See: CARBONIZATION
COAL TAR PITCH
GREEN COKE

Note:

SEMICOKE may be conceived as covering a continuous range from coal that has not yet been fused to COKE BREEZE. SEMICOKE can also be used as a FILLER in carbon mixtures.

See: COKE BREEZE
FILLER

SOOT

Description:

SOOT is a randomly formed PARTICULATE CARBON material and may be coarse, fine, and/or colloidal in proportions dependent on its origin. SOOT consists of variable quantities of carbonaceous and inorganic solids together with absorbed and occluded tars and resins.

See: PARTICULATE CARBON

Notes:

SOOT is generally formed as an unwanted by-product of incomplete combustion or pyrolysis. SOOT generated within flames consists essentially of aggregates of spheres of carbon. SOOT found in domestic fireplace chimneys contains few aggregates but may contain substantial amounts of particulate fragments of COKE or CHAR. SOOT from diesel engines consists essentially of aggregates together with tars and resins. For historical reasons, the term SOOT is sometimes incorrectly used for CARBON BLACK. This misleading use should be avoided.

See: CARBON BLACK
CHAR
COKE

SPHERICAL CARBONACEOUS MESO-PHASE
Description:
The term SPHERICAL CARBONACEOUS MESOPHASE describes the morphology of CARBONACEOUS MESOPHASE which is formed in the isotropic PITCH matrix. The SPHERICAL CARBONACEOUS MESOPHASE usually has a lamellar structure consisting of flat aromatic molecules arranged in parallel layers which are perpendicular to the sphere/isotropic phase interface as described by BROOKS AND TAYLOR. On coalescence, this spherical mesophase loses its characteristic morphology and is converted to the BULK MESOPHASE.
See: BROOKS AND TAYLOR STRUCTURE
BULK MESOPHASE
CARBONACEOUS MESOPHASE
PITCH

STABILIZATION TREATMENT OF THERMOPLASTIC PRECURSOR FIBRES FOR CARBON FIBRES
Description:
STABILIZATION TREATMENT is a process applied to fusible organic precursor fibres for CARBON FIBRES with the aim of obtaining non-fusible polymer fibres suitable for subsequent CARBONIZATION. The original fibre shape is maintained.
See: CARBON FIBRES
CARBONIZATION

Notes:
The STABILIZATION TREATMENT of thermoplastic precursor fibres for CARBON FIBRES is usually a heat treatment process performed in an oxidizing atmosphere above 470 K. For STABILIZATION TREATMENT of polyacrylonitrile (PAN) fibres, 600 K is the highest temperature up to which cyclization, dehydrogenation and oxidation processes prevail.
See: CARBON FIBRES

STRESS GRAPHITIZATION
Description:
STRESS GRAPHITIZATION refers to the solid-state transformation of NON-GRAPHITIC CARBON into GRAPHITE by heat treatment combined with application of mechanical stress, resulting in a defined degree of GRAPHITIZATION being obtained at a lower temperature and/or after a shorter time of heat treatment than in the absence of applied stress.
See: GRAPHITE
GRAPHITIZATION
NON-GRAPHITIC CARBON

Note:
STRESS GRAPHITIZATION may also occur in volume elements of a carbon body in the process of heat treatment as a result of the action of internal residual or thermal stresses.

SYNTHETIC GRAPHITE
Description:
SYNTHETIC GRAPHITE is a material consisting of GRAPHITIC CARBON which has been obtained by graphitizing of NON-GRAPHITIC CARBON, by chemical vapour deposition (CVD) from hydrobcarbons at temperatures above 2500 K, by decomposition of thermally unstable carbides or by crystallizing from metal melts supersaturated with carbon.
See: GRAPHITIC CARBON
GRAPHITIZATION
NON-GRAPHITIC CARBON

Notes:
The term ARTIFICIAL GRAPHITE is often used as a synonym for SYNTHETIC GRAPHITE. The term SYNTHETIC GRAPHITE is preferred, however, since graphite crystals can be considered to consist of carbon macromolecules. Although the term SYNTHETIC GRAPHITE also covers the CVD product PYROLYTIC GRAPHITE as well as the residues of carbide decomposition, it is predominantly used for GRAPHITIZED CARBON. Such common use is in line with the above definition. Synonyms for this most important type of SYNTHETIC GRAPHITE are ACHESON GRAPHITE and ELECTROGRAPHITE.

See: ACHESON GRAPHITE
ARTIFICIAL GRAPHITE
ELECTROGRAPHITE
GRAPHITIZED CARBON
PYROLYTIC GRAPHITE

THERMAL BLACK

Description:
THERMAL BLACK is a special type of CARBON BLACK produced by pyrolysis of gaseous hydrocarbons in a preheated chamber in the absence of air. THERMAL BLACK consists of relatively large individual spheres (100 - 500 nm diameter) and aggregates of a small number of pseudospherical particles. The preferred alignment of the layer planes is parallel to the surface of the spheres.

See: CARBON BLACK

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