

## Glossary

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| <b>Abrasion</b>             | The process of rubbing, grinding, or wearing away by the use of abrasives; a roughening or scratching of a surface due to abrasive wear [1].  |
| <b>Abrasive</b>             | A substance capable of removing material from another substance in machining, abrasion, or polishing that usually takes the form of several small, irregular shaped particles of hard material [1].   |
| <b>Abrasive disk</b>        | (1) Grinding wheel mounted on a steel plate, with the exposed flat side being used for grinding. (2) Grinding disk with a layer of abrasive product [1].  |
| <b>Abrasive paper</b>       | See <i>Grinding paper</i> .   |
| <b>Abrasive wet cutting</b> | Cutting method for almost all solid materials using mechanical friction and wear with abrasives bonded in a cut-off wheel (similar to grinding) [3].  |
| <b>Achromatic</b>           | Literally, color-free. A lens or prism is said to be achromatic when corrected for two colors. The remaining color seen in an image formed by such a lens is said to be secondary chromatic aberration [2]. See <i>Achromatic objective</i> .   |
| <b>Achromatic objective</b> | An objective that is corrected chromatically for two colors, and spherically for one, usually in the yellow-green part of the spectrum [2].   |
| <b>Acid</b>                 | A chemical substance that yields hydrogen ions ( $H^+$ ) when dissolved in water gives a pH of less than 7 [1]. See also <i>Base</i> .  |
| <b>Age hardening</b>        | Hardening through aging, usually after rapid cooling or cold working [1]. See also <i>Precipitation hardening</i> .   |
| <b>Aging</b>                | A change in the property of certain metals and alloys that occurs at room temperature or slightly elevated temperatures, after hot working or heat treatment, or after cold working. The aging is usually due to phase changes (precipitation) [1]. See also <i>Precipitation hardening</i> . |
| <b>Air-hardening steel</b>  | A steel containing sufficient carbon and other alloying elements to harden fully during cooling in air or other gaseous media from a temperature above its transformation range. Same as self-hardening steel [1].  |
| <b>Alloy</b>                | A substance having metallic properties and being composed of two or more chemical elements of which at least one is an elemental metal [1].   |
| <b>Alloying element</b>     | An element added to a metal (and which remains within the metal) to effect changes of properties [1].   |
| <b>Alloy steel</b>          | Steel containing significant quantities of alloying elements (other than carbon and the commonly accepted amounts of manganese, copper, silicon, sulfur, and phosphorus) to improve the mechanical properties [1].  |
| <b>Alpha brass</b>          | Solid solution phase of one or more alloying elements in copper and having the same crystal lattice as copper [2].  |
| <b>Alpha iron (Fe)</b>      | Solid phase of pure iron [2].   |
| <b>Amalgam</b>              | Alloy with mercury and one or more other metals [3].  |
| <b>Amorphous</b>            | Not having a crystal structure; noncrystalline [1].   |

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| <b>Anisotropy</b>               | Characterized by having different values of a property in different crystallographic directions [1].   |
| <b>Annealing</b>                | Heating to and holding metals and alloys at a suitable temperature followed by cooling at a suitable rate, used primarily to soften metals, but also to simultaneously produce desired changes in properties or in microstructure [3]. |
| <b>Anode</b>                    | Electrode where electrons leave (current enters) an operating system (battery, X-ray tube, electrolytic cell) [3]. See also <i>Cathode</i> .   |
| <b>Anode corrosion</b>          | The dissolution of a metal acting as an anode [3].   |
| <b>Anodic etching</b>           | See <i>Electrolytic etching</i> .  |
| <b>Anvil effect</b>             | The effect caused by use of too high a load, or when testing the hardness of too thin a specimen, resulting in a bulge or shiny spot on the underside of the specimen [2].   |
| <b>Aperture, optical</b>        | The working diameter of a lens or a mirror [2].  |
| <b>Apochromatic objective</b>   | An objective with longitudinal chromatic correction for red, green, and blue, and spherical chromatic correction for green and blue. This is the best choice for high resolution or color photomicrography [2].                        |
| <b>Arc cutting</b>              | A group of cutting processes that melts the metals to be cut with the heat of an arc between an electrode and the base material [1].   |
| <b>Artifact</b>                 | A false microstructural feature that is not an actual characteristic of the specimen; it may be present as a result of improper or inadequate preparation, handling methods, or optical conditions for viewing [2].                    |
| <b>Attack polishing</b>         | Simultaneous etching and mechanical polishing by adding a weak etching solution to the polishing compound [1]. See also <i>Chemical mechanical polishing</i> .   |
| <b>Austenite</b>                | A face-centered cubic solid solution of carbon or other elements in gamma iron [2].  |
| <b>Austenitic steel</b>         | An alloy steel whose structure is austenitic at room temperature [1].  |
| <b>Automatic image analysis</b> | A device which can be programmed to detect and measure features of interest in an image. It may include accessories such as automatic focus and an automatic traversing stage to permit unattended operation [2].                      |

**Bainite—upper,  
lower, intermediate**

Metastable microstructure or microstructures resulting from the transformation of austenite at temperatures between those which produce pearlite and martensite. These structures may be formed on continuous (slow) cooling if the transformation rate of austenite to pearlite is much slower than that of austenite to bainite. Ordinarily, these structures may be formed isothermally at temperatures within the above range by quenching austenite to a desired temperature and holding for a period of time necessary for transformation to occur. If the transformation temperature is just below that at which the finest pearlite is formed, the bainite (upper bainite) has a feathery appearance. If the transformation temperature is just above that at which martensite is produced, the bainite (lower bainite) is acicular, resembling slightly tempered martensite. At the higher resolution of the electron microscope, upper bainite is observed to consist of plates of cementite in a matrix of ferrite. These discontinuous carbide plates tend to have parallel orientation in the direction of the longer dimension of the bainite areas. Lower bainite consists of ferrite needles containing carbide platelets in parallel array cross-striating each needle axis at an angle of about 60°. Intermediate bainite resembles upper bainite; however, the carbides are smaller and more randomly oriented [2].

**Banded structure  
(banding)**

Alternate bands parallel with the direction of working resulting from the elongation of segregated areas [2].

**Band saw**

Mechanical cutting method using an endless steel saw blade.

**Base**

A chemical substance that yields hydroxyl ions ( $\text{OH}^-$ ), when dissolved in water gives a pH of more than 7 [1].

**Base metal**

(1) After welding, that part of the metal which was not melted. (2) A metal that readily oxidizes, or that dissolves to form ions [1]. See also *Noble metal*.

**Beilby layer**

A layer of amorphous or amorphous-like character developed on the surface of a specimen during mechanical polishing. Theory by G. Beilby, but later research has shown that the layer does not exist.

**Beta structure**

Structurally analogous body-centered cubic phases (similar to beta brass), or electron compounds, that have ratios of 3 valence electrons to 2 atoms [2].

**Binder**

Cementing medium holding together mixtures of particles or powder [3].

**Blow torch**

Method for cutting metal using an acetylen burner, with the possibility of adding an extra flow of oxygen, melting, and blowing away the material. Also called oxyacetylen torching.

**Bond**

The material that binds the abrasive in a cut-off wheel and in other abrasive products.

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| <b>Brass</b>                                   | Alloy consisting of copper (over 50 %) and zinc, to which small amounts of other elements may be added [3].   |
| <b>Brightfield illumination</b>                | For reflected light, the illumination which causes specularly reflected surfaces normal to the axis of a microscope to appear bright. For transmission electron microscopy, the illumination of an object so that it appears on a bright background [2].  |
| <b>Brinell hardness testing</b>                | Hardness test performed by forcing a hard steel or tungsten carbide ball of specified diameter into a material [3].   |
| <b>Brittleness</b>                             | The tendency of a material to fracture without first undergoing significant plastic deformation [1]. See also <i>Ductility</i> .  |
| <b>Bronze</b>                                  | Copper-tin alloy with or without small amounts of other alloying elements such as phosphorus and zinc [3].  |
| <b>Burning metallography/ materialography)</b> | Can occur in cutting and grinding, when sufficient heat is generated on the surface of the work piece to cause discoloration or a change of the microstructure by tempering or hardening [1].   |
| <b>Calibration</b>                             | (1) The act or process of determining the relationship between a set of standard units of measure and the output of an instrument or test procedure. (2) The graphical or mathematical relationship relating the desired property (expressed in a standard unit of measure such as micrometres or Kg/mm <sup>2</sup> ) to the instrument output (instrument units such as filar divisions or pixels) [2]. |
| <b>Carbide</b>                                 | A compound of carbon with one or more elements, which, in customary formulation, are considered as being more positive than carbon [2].   |
| <b>Carbide tools</b>                           | Cutting or forming tools, usually made of tungsten, titanium, tantalum, or niobium carbides or a combination of them in a matrix of cobalt, nickel, or other metals. Carbide tools are characterized by high hardness and compressive strength and may be coated to improve wear resistance [1].  |
| <b>Carbon steel</b>                            | Steel containing carbon up to 2 % [3].  |
| <b>Carbonitriding</b>                          | A case-hardening process by which a suitable ferrous metal is heated in a gaseous atmosphere. Through the gas, the metal surface will absorb carbon and nitrogen by diffusion and form a very hard compound layer [1].  |
| <b>Carburizing</b>                             | Absorption and diffusion of carbon into solid ferrous alloys by heating to a temperature usually above Ac <sub>3</sub> , in contact with a suitable carbonaceous material. A form of case hardening [1]. See also <i>Case hardening</i> .   |
| <b>Case</b>                                    | In a ferrous alloy, the outer portion that has been made harder than the inner portion as a result of altered composition, or structure, or both, from treatments such as carburizing, nitriding, and induction hardening [2]. See also <i>Core</i> .   |

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| <b>Case hardening</b>                        | A generic term covering several processes applicable to steel that change the chemical composition of the surface layer by absorption of carbon, nitrogen, or a mixture of the two by diffusion. It is also called carburizing, nitriding, carbonitriding, cyaniding, nitrocarburizing, and quench hardening [1].   |
| <b>Cast iron</b>                             | Generic term of a large family of cast ferrous alloys containing 2.5–4 % carbon and about 1–3 % silicon. The carbon content exceeds the solubility of carbon in austenite that exists at the eutectic temperature, which is usually more than 2 % [3].  |
| <b>Cast structure</b>                        | The structure, on a macroscopic or microscopic scale, of a casting [2]. See also <i>Dendrites</i> .   |
| <b>Cathode</b>                               | Electrode where the electrons enter (current leaves) an operating system [3]. See also <i>Anode</i> .   |
| <b>Cemented carbides (sintered carbides)</b> | Material made by pressing and sintering a powder of one or more metallic carbides with a small amount of metal (cobalt) serving as a binder [1].  |
| <b>Cementite</b>                             | A very hard and brittle compound of iron and carbon corresponding to the empirical formula $\text{Fe}_3\text{C}$ . It is commonly known as iron carbide and possesses an orthorhombic lattice. In “plain-carbon steels” some of the iron atoms in the cementite lattice are replaced by manganese, and in “alloy steels” by other elements such as chromium or tungsten. Cementite will often appear as distinct lamellae or as spheroids or globules of varying size in hypo-eutectoid steels. Cementite is in metastable equilibrium and has a tendency to decompose into iron and graphite, although the reaction rate is very slow [2]. |
| <b>Ceramic</b>                               | Inorganic, nonmetallic material with crystalline and noncrystalline structures (for instance: metal carbides, oxides, nitrides, and borides are ceramics) [3].  |
| <b>Cermets</b>                               | Powder metallurgy product consisting of ceramic particles bonded with metal [1].  |
| <b>CG iron</b>                               | Same as compacted graphite cast iron [1]. See also <i>Compacted cast iron</i> .   |
| <b>Chemical deposition</b>                   | Precipitation of a metal from solutions of its salts through the introduction of another metal or reagent to the solution [1].  |
| <b>Chemical etching</b>                      | Develops the microstructure by using an electrochemical process, which takes advantage of the differences in the electrochemical potentials of the various constituents in the structure [3].   |
| <b>Chemical polishing</b>                    | Improving the surface luster of a metal by chemical treatment [1]. See also <i>Chemical mechanical polishing</i> .  |

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| <b>Chemical mechanical polishing</b> | Using a combination of a chemical solution (usually an etchant) with an oxide suspension on a polishing cloth, resulting in a scratch free surface. Mainly used for very soft or ductile metals [3]. See also <i>Oxide polishing</i> .   |
| <b>Chips</b>                         | Pieces of material removed from a work piece by cutting tools or by an abrasive medium [3].  |
| <b>Clad metal</b>                    | A composite metal containing two or three layers that have been bonded together. The bonding may have been accomplished by co-rolling, welding, casting, heavy chemical deposition, or heavy electroplating [1].   |
| <b>Clay</b>                          | Earthy or stony mineral aggregate, which is plastic when sufficiently pulverized and wetted, rigid and dry, and vitreous when fired at a sufficiently high temperature [3].  |
| <b>Cold etching</b>                  | Reveals the microstructure at room temperature and below [4].  |
| <b>Cold rolled sheet</b>             | Sheets of metal made by feeding metal through mill rolls at room temperature [3].  |
| <b>Cold worked structure</b>         | A microstructure resulting from plastic deformation of a metal or alloy below its recrystallization temperature [1].   |
| <b>Combined carbon</b>               | That part of the total carbon in steel or cast iron that is present as other than free carbon [1]. See also <i>Free carbon</i> .   |
| <b>Comet tails</b>                   | Artifact in the form of unidirectional scratches developed by mechanical polishing of a metallographic/materialographic surface.   |
| <b>Compacted graphite cast iron</b>  | Cast iron having a graphite shape intermediate between the flake form typical of gray cast iron and the spherical form of fully spherulitic cast iron. Also known as CG iron [1].  |
| <b>Component</b>                     | One of the independently variable substances by means of which the composition of each phase of a system of heterogeneous equilibrium may be described completely; usually an element, or a compound that remains undissociated throughout the range of temperature and pressure concerned [2].  |
| <b>Composite material</b>            | A heterogeneous, solid structural material consisting of two or more distinct components that are mechanically or metallurgically bonded together (such as a cermet, or boron wire embedded in a matrix of epoxy resin) [1]. See also <i>Cermet</i> .  |
| <b>Condenser</b>                     | A term applied to lenses or mirrors designed to collect, control, and concentrate radiation in an illumination system [2].   |
| <b>Constant feed speed</b>           | In cutting: Cutting principle where the movement of the specimen or the cut-off wheel is kept constant throughout the cutting process. This cutting principle is preferred to the principle of Constant force as it will produce the least deformation possible while still achieving the shortest cutting times [3]. See also <i>Constant force</i> . |

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| <b>Constant force</b>   | In cutting: Cutting principle where the force applied is kept constant throughout the cutting process. Constant force can produce damage to the sample especially at sample entry and exit [3].   |
| <b>Constituent</b>  | A phase, or combination of phases, which occurs in a characteristic configuration in an alloy microstructure [2].   |
| <b>Contamination<br/>(metallography/<br/>materialography)</b> | (1) Debris from grinding or dust from the lab environment contaminating a polishing cloth resulting in scratches of the specimen surface. (2) Material from a source other than the specimen itself, which is deposited on the specimen surface during preparation [3]. |
| <b>Continuous phase</b>                                       | The phase forming the matrix or background in which other phases may be dispersed as isolated units [2].  |
| <b>Controlled etching</b>                                     | Electrolytic etching with selection of suitable etchant and voltage, resulting in a balance between current and dissolved ions [4].   |
| <b>Conversion,<br/>hardness</b>                               | The exchange of a hardness number determined by one method for an equivalent hardness number of a different scale [2].  |
| <b>Coolant</b>  | See <i>Cutting fluid</i> .  |
| <b>Core</b>   | (1) Case hardening—interior portion of unaltered composition, or microstructure, or both, of a case-hardened steel article. (2) Clad products—the central portion of a multilayer composite metallic material [2].  |
| <b>Corrosion</b>  | Deterioration of a metal by chemical or electrochemical reaction with its environment [1].  |
| <b>Corrosion<br/>embrittlement</b>                            | The chemical or electrochemical reaction between a material, usually a metal, and its environment that produces a deterioration of the material and its properties [1].   |
| <b>Corrosion fatigue</b>                                      | Cracking produced by the combined action of repeating and fluctuating stress and a corrosive environment [1].   |
| <b>Coupon</b>   | A piece of material especially made for testing. Known from printed circuit boards, where a coupon is made together with the board.   |
| <b>Creep</b>  | Time-dependent strain occurring under stress [1].   |
| <b>Crystal</b>  | A solid composed of atoms, ions, or molecules arranged in a pattern which is periodic in three dimensions [2].  |
| <b>Crystallite</b>  | A crystalline grain not bounded by habit planes [2].  |
| <b>Cut-off wheel</b>  | Abrasive wheel consisting of an abrasive in a bond for cutting any material or part [3].  |
| <b>Cutting<br/>(metallography/<br/>materialography)</b>       | Sectioning of a piece of material to obtain a specimen [3].<br>See also <i>Cut-off wheel</i> .  |
| <b>Cutting fluid</b>  | Fluid used to cool a work piece, wash chips away, and improve surface finish and cut-off wheel lifetime [3].  |

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| <b>Cutting speed</b>                               | The linear or peripheral speed of relative motion between the tool and work piece in the principal direction of cutting [1].  |
| <b>Darkfield illumination</b>                      | The illumination of an object such that it appears illuminated with the surrounding field dark. This results from illuminating the object with rays of sufficient obliquity so that none can enter the objective directly. As applied to electron microscopy, the image is formed using only electrons scattered by the object [2].   |
| <b>Decarburization</b>                             | Loss of carbon from the surface of a carbon-containing alloy due to a reaction with one or more chemical substances in a medium that contacts the surface. Decarburization may be either (1) partial. That is, where carbon content is less than the unaffected interior but greater than the room temperature solubility limit of carbon in ferrite or (2) complete. That is, where carbon content is less than the solubility limit of carbon in ferrite so that only ferrite is present [2]. |
| <b>Deep drawing</b>                                | Forming of deeply recessed parts by means of plastic flow of the material [1].  |
| <b>Deep etching</b>                                | Macroetching; etching preliminary to macro-examination, intended to develop gross features such as segregation, grain flow, cracks, or porosity [2]. See also <i>Macroetching</i> .   |
| <b>Deformation (metallography/materialography)</b> | Plastic deformation, which may also be referred to as cold work, can result in subsurface defects after grinding, lapping, or polishing. Remaining plastic deformation can first be seen after etching. Plastic deformation (deformed layer) is an artifact that has to be removed during sample preparation [3].   |
| <b>Deformation bands</b>                           | Bands produced within individual grains during cold working which differ variably in orientation from the matrix [2].   |
| <b>Dendrites</b>                                   | Crystals, usually formed during solidification or sublimation, which are characterized by a tree-like pattern composed of many branches; pine-tree or fir-tree crystals [2].  |
| <b>Depth of field</b>                              | The depth or thickness of the object space that is simultaneously in acceptable focus [2].  |
| <b>Diamond polishing</b>                           | Polishing using diamond as abrasive. Removes scratches introduced during fine grinding. Makes the specimen suitable for microscopic observation [3]. See also <i>Final polishing</i> , <i>Polishing</i> .   |
| <b>Diamond wheel</b>                               | A grinding wheel in which crushed and sized industrial diamonds are held in a resinoid, metal, or vitrified bond [1].   |
| <b>Diaphragm</b>                                   | A fixed or adjustable aperture in an optical system. Diaphragms are used to intercept scattered light, to limit field angles, or to limit image-forming bundles or rays [1].  |



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| <b>Differential interference contrast illumination (DIC)</b> | A microscopical technique employing a beam-splitting double-quartz prism; that is a modified Wollaston prism placed ahead of the objective with a polarizer and analyzer in the 90° crossed positions. The two light beams are made to coincide at the focal plane of the objective, thus rendering height differences visible as variations in color. The prism can be moved, shifting the interference image through the range of Newtonian colors [2].  |
| <b>Diffraction</b>   | (1) A modification which radiation undergoes, as in passing by the edge of opaque bodies or through narrow slits, in which the rays appear to be deflected. (2) Coherent scattering of X-radiation by the atoms of a crystal which necessarily results in beams in characteristic directions. Sometimes called reflection. (3) The scattering of electrons, by any crystalline material, through discrete angles depending only on the lattice spacings of the material and the velocity of the electrons [2]. |
| <b>Diffusion</b>   | The spontaneous movement of atoms or molecules to new sites within a material [1].   |
| <b>Direct cut (metallography/materialography)</b>            | Cutting mode in which the cut-off wheel cuts directly through the work piece; also called chop cutting [3].  |
| <b>Dislocation</b>   | A linear imperfection in a crystalline array of atoms [1].   |
| <b>Dislocation etching</b>                                   | Reveals exit point of dislocations on the specimen surface [4].  |
| <b>Dissolution etching</b>                                   | Reveals the microstructure by surface removal [4].   |
| <b>Double etching</b>  | Two etchants are used sequentially; the second one will accentuate a particular microstructural feature [4].   |
| <b>Drawing</b>   | Forming recessed parts of metal by pressing them in or through a die. Reducing cross section of a wire or tube by pulling it through a die [1].  |
| <b>Drop etching</b>  | Placing a drop of an etchant on a selected area of the specimen surface to develop the microconstituents [4].  |
| <b>Dry etching</b>   | Develops the microstructure by gaseous exposure [4].   |
| <b>Ductile cast iron</b>                                     | A cast iron that has been treated while molten with an element such as magnesium or cerium to induce the formation of free graphite as nodules or spherulites, which imparts a measurable degree of ductility to the cast metal. Also known as nodular cast iron, cast iron with spheroidal graphite and SG iron [1].  |
| <b>Ductility</b>   | Ability of a material to deform plastically without fracturing, measured by elongation or reduction of area in a tensile test [1]. See also <i>Brittleness</i> .   |
| <b>Duplex microstructure</b>                                 | A two-phase structure [2].   |
| <b>Dye penetrant</b>   | Color spray used in nondestructive testing to find cracks in surface of parts [3].   |

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| <b>Elastic deformation</b>                  | Change of dimensions of a piece of material under stress. Upon release of stress original dimensions are restored again (example: elastic band which takes its original shape after it has been stretched) [3].  |
| <b>Elasticity</b>                           | Ability of a solid to deform in direct proportion to and in phase with increases or decreases in applied force [3].  |
| <b>Electrical discharge machining (EDM)</b> | Removal of stock from an electrically conductive material by rapid, repetitive spark discharge through a dielectric fluid flowing between the work piece and a shaped electrode [1].   |
| <b>Electrolyte</b>                          | Liquid, most often a solution, that will conduct an electric current [1].  |
| <b>Electrolytic cell</b>                    | An assembly consisting of a vessel, electrodes (anode and cathode) and an electrolyte in which electrolysis can be carried out [1].  |
| <b>Electrolytic etching</b>                 | Development of microstructure by selective dissolution of the polished surface under application of a direct current [1]. Also called anodic etching.  |
| <b>Electrolytic polishing</b>               | A metallographic preparation procedure where metal is preferentially dissolved from high points on an anodic surface by passage of an electric current through a conductive bath, to produce a specular reflecting surface. Used as an alternative to mechanical polishing [2].  |
| <b>Electron microscopy</b>                  | The study of materials by means of the electron microscope [2]. See also <i>SEM</i> and <i>TEM</i> .   |
| <b>Embedded abrasives</b>                   | Loose abrasive particles pressed into the surface of a specimen. This happens mainly with soft or ductile materials, or both. Abrasives can be embedded when using a small abrasive particle size, the grinding or polishing cloth used has a low resilience or a lubricant with a low viscosity is used or a combination of these conditions takes place [3]. |
| <b>Equiaxed grain</b>                       | A polygonal crystallite, in an aggregate, whose dimensions are approximately the same in all directions [2].   |
| <b>Equilibrium diagram</b>                  | A graphical representation of the temperature, pressure, and composition limits of phase fields in an alloy system, as they exist under conditions of complete equilibrium [1].  |
| <b>Etchant</b>                              | Chemical substance or mixture used for etching [1].  |
| <b>Etch figures</b>                         | Markings formed on a crystal surface by etching or chemical solution and usually related geometrically to the crystal structure [2].   |
| <b>Etching</b>                              | Controlled preferential attack on a metal surface for the purpose of revealing structural details [2].   |
| <b>Eutectic</b>                             | Phase consisting of intermixed solid constituents formed by a eutectic reaction, (pearlite=ferrite and cementite). The number of solids being the same as the number of components in the system [3].  |
| <b>Eutectic structure</b>                   | The structure resulting when an alloy has passed through a eutectic equilibrium upon freezing [2].   |

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| <b>Exogenous inclusions</b>                   | A nonmetallic constituent produced by entrapment of foreign material in the melt [2]. See also <i>Inclusions</i> , <i>Nonmetallic inclusions</i> .                                      |
| <b>Eyepiece</b>                               | The lens system used in an optical instrument for magnification of the image formed by the objective [2].   |
| <b>Fatigue</b>                                | Process by which repeated or fluctuating stress, or both, leads to fracture [3].  |
| <b>Feed speed</b>                             | Rate by which a tool or cut-off wheel advances along or into the surface of a work piece [3].   |
| <b>Ferrite</b>                                | Designation commonly assigned to alpha iron containing alloying elements in solid solution. Increasing carbon content markedly decreases the high-temperature limit of equilibrium [2]. |
| <b>FG</b>                                     | Fine Grinding. Reduces surface roughness of a specimen to a degree that is suitable for polishing [3].  |
| <b>Field</b>                                  | The portion of the object in view [2].  |
| <b>Field metallography</b>                    | Metallographic techniques carried out in the field when the part or component is too large to bring to a metallographic laboratory or a specimen cannot be removed [1].                 |
| <b>Filar</b>                                  | An eyepiece equipped with a fiducial line in its focal plane, which is movable by means of a calibrated micrometre screw, in order to make accurate measurements of length [2].         |
| <b>Filler</b>                                 | Material used to increase the bulk of a product without adding to its effectiveness in functional performance [3].  |
| <b>Final polishing</b>                        | The final step in a specimen preparation process producing a surface suitable for microscopic examination.  |
| <b>Flame spraying</b>                         | Coating technique in which the coating material is fed as wire or powder into a flame and sprayed in the molten state against the surface to be coated [3].                             |
| <b>Flow lines</b>                             | A fiber pattern, frequently observed in wrought metal, which indicates the manner in which the metal flowed during deformation [2].   |
| <b>Fluorescent screen</b>                     | A sheet of material which emits visible light when exposed to invisible radiation [2].  |
| <b>Foil</b>                                   | A thin sheet of a material, usually a metal, not exceeding 0.13 mm (0.005 in.) in thickness [2].  |
| <b>Forging</b>                                | Process of plastically deforming metal, usually hot, into a desired shape with compressive force, with or without dies [1].   |
| <b>Formability (workability, drawability)</b> | Relative ease with which a metal can be shaped through plastic deformation [1].   |
| <b>Fractography</b>                           | Description of fractures with macrographs ( $<25\times$ ) and micrographs at high magnification ( $>25\times$ ) from the optical microscope and the SEM [3].                            |

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| <b>Fracture test</b>          | Test in which a specimen is broken and its fracture surface examined to determine such factors as composition, grain size, case depth, or soundness [1].  |
| <b>Free carbon</b>            | Part of the total carbon in steel or cast iron that is present in elemental form as graphite [1]. See also <i>Combined carbon</i> .   |
| <b>Free machining</b>         | Machining capabilities of an alloy to which one or more ingredients have been introduced to produce small broken chips, better surface finish, and longer tool lifetime during the machining process [1].   |
| <b>Galvanizing</b>            | Coating the surface of iron or steel with zinc applied electrolytically or by hot dipping [3].  |
| <b>Goniometer</b>             | An instrument devised for measuring the angle through which a specimen is rotated [1].  |
| <b>Grain</b>                  | An individual crystallite in metals [2].  |
| <b>Grain boundary</b>         | An interface separating two grains, where the orientation of the lattice changes from that of one grain to that of the other. When the orientation change is very small the boundary is sometimes referred to as a subboundary [2].   |
| <b>Grain boundary etching</b> | Reveals the intersections of the individual grains. Grain boundaries have a higher dissolution potential than the individual grains because of their high density of structural defects. Accumulation of impurities in grain boundaries increases this effect [4].  |
| <b>Grain size</b>             | (1) Measure of the areas or volume of grains in a polycrystalline material, usually expressed as an average when the individual sizes are fairly uniform. In metals containing two or more phases, grain size refers to that of the matrix unless otherwise specified. Grain size is reported in terms of number of grains per measuring unit area or volume, average diameter, or as a grain size derived from area measurements. See also ASTM Standard E 112. (2) Dimension of one individual particle of an abrasive, measured in micrometres, $\mu\text{m}$ [1]. See also <i>Grit size</i> . |
| <b>Grain-contrast etching</b> | Etching the surface of the grains according to their crystal orientation. They become distinct by the different reflectivity caused by reaction layers or surface roughness [4].  |
| <b>Graphite</b>               | The polymorph of carbon with a hexagonal crystal structure [1]. See also <i>CG iron</i> , <i>Gray cast iron</i> , <i>Nodular cast iron</i> , <i>Spheroidal cast iron</i> .  |
| <b>Graphitic carbon</b>       | Free carbon in steel or cast iron [1].  |
| <b>Graticule</b>              | A scale on glass or other transparent material placed in the eyepiece or at an intermediate plane on the optic axis of a light microscope for the location and measurement of objects (a graticule is different than a reticle) [2]. See also <i>Reticle</i> .  |

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| <b>Gray cast iron or gray iron</b>   | Cast iron that looks gray on the fractured surface due to the presence of free graphite. Contains carbon as graphite in form of flakes or nodules [3].  |
| <b>Grinding</b>                      | The removal of material from the surface of a specimen by abrasion through the use of randomly oriented hard-abrasive particles bonded to a suitable substrate, such as paper or cloth, where the abrasive particle size is generally in the range of 60 to 600 grit (approximately 150 to 15 $\mu\text{m}$ ) but may be finer [2].                                   |
| <b>Grinding paper</b>                | Coated abrasive product in which paper is used as a backing material [3].   |
| <b>Grit size</b>                     | Nominal size of abrasive particles in a grinding wheel, corresponding to the number of openings per linear inch in a screen through which the particles can just pass. Sometimes but inadvisably called "grain size" [1]. See <i>Grain size</i> .   |
| <b>Half moon phenomenon</b>          | Appears mainly when using wet grinding disk and coarse SiC-paper for plane and fine grinding of specimens clamped in a specimen holder. This phenomenon is due to the fact that the abrasive grains of the SiC-paper are not getting worn down at the edge of an SiC-paper as fast as in the middle, combined with the higher speed at the periphery of the disk [3]. |
| <b>Hardening</b>                     | Increasing hardness of a metal with a suitable treatment, usually through heating and fast cooling [1].   |
| <b>Hardness (indentation)</b>        | Resistance of a metal to plastic deformation, usually by indentation. However, the term may also refer to resistance to scratching, abrasion, or cutting. Indentation hardness may be measured by various hardness testing methods, such as Brinell, Rockwell, Vickers, Knoop, and Scleroscope [3].   |
| <b>Heat-resistant alloy</b>          | Alloys used for applications for which resistance against high temperature and corrosion, combined with high stresses are required. They are usually high nickel alloys [1].  |
| <b>Heat tinting</b>                  | Coloration of a metal surface through a thin oxide film, formed by heating in oxidizing atmosphere, to reveal details of the microstructure [1].  |
| <b>Heat treatment</b>                | Heating and cooling a solid metal or alloy in such a way that desired properties are obtained [1].  |
| <b>Heterogenous High alloy steel</b> | Nonuniform in microstructure or composition [2].<br>Contains up to 2.5 % carbon and more than 6 % metallic alloying elements, mainly chromium (Cr), nickel (Ni), vanadium (V), tungsten (W), and manganese (Mn). Very hard tool steels and ductile stainless steels are high alloy steels [3].  |
| <b>Homogenizing</b>                  | Holding at high temperature to eliminate or decrease chemical segregation by diffusion [1].   |

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| <b>Hot dip coating</b>                              | Metallic coating obtained by dipping the basic metal into a molten metal [1].   |
| <b>Hot etching</b>                                  | Development and stabilization of the microstructure at elevated temperature in etching solutions or gases [4].  |
| <b>Identification (selective) etching</b>           | Etching for the identification of particular microconstituents without attacking any others [4].  |
| <b>Image</b>  | A representation of an object produced by means of radiation, usually with a lens or mirror system [2].   |
| <b>Image processing, in image analysis</b>          | The computer modification of a digitized image on a pixel-by-pixel basis to emphasize or de-emphasize certain aspects of the image [2]. See also <i>Automatic image analysis</i> .  |
| <b>Immersion etching</b>                            | The specimen is immersed in the etchant with the polished surface up and is agitated. This is the most common etching method [4].   |
| <b>Immersion objective</b>                          | An objective in which a medium of high refractive index is used in the object space to increase the numerical aperture and hence the resolving power of the lens [2].   |
| <b>Impact test</b>                                  | A test to determine the behavior of materials when subjected to high rates of loading, usually bending, tension, and torsion. The quantity measures the energy absorbed in breaking the specimen by a single blow, as in Charpy and Izod tests [1].                             |
| <b>Impregnation (metallography/materialography)</b> | Process of filling voids and cracks under vacuum with a sealing medium, for instance, epoxy cold mounting resin [3].  |
| <b>Impression</b>                                   | (1) Electron microscopy. The reproduction of the surface contours of a specimen formed in a plastic material after the application of pressure and heat, or both.<br>(2) Hardness. The imprint or dent made in the specimen by the indenter of a hardness-measuring device [2]. |
| <b>Impurities</b>                                   | Elements or compounds whose presence in a material is undesired [1].  |
| <b>Inclusions</b>                                   | Foreign material held mechanically, usually referring to nonmetallic particles, such as oxides, sulfides, silicates, etc. [2]. See also <i>Exogenous inclusions</i> , <i>Nonmetallic inclusions</i> .   |
| <b>Indentation hardness</b>                         | Resistance of a material to indentation. This is the usual type of hardness test, in which a pointed or rounded indenter is pressed into a surface under a substantially static load [3]. See also <i>Hardness</i> .  |
| <b>Indigenous (endogenous) inclusion</b>            | A nonmetallic material that precipitates from the melt [2]. See <i>Inclusions</i> .   |
| <b>Induction hardening</b>                          | Surface hardening in which only the surface layer of a suitable ferrous work piece is heated by electrical induction to hardening temperature and then quenched [3].  |
| <b>Ingot</b>  | Casting of a simple shape suitable for hot working or remelting [1].  |

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| <b>Intercrystalline</b>         | Between crystals, or between grains of a metal, the same as intergranular [1].  |
| <b>Intercrystalline cracks</b>  | Cracks or fractures that occur between the grains or crystals in a polycrystalline aggregate [2].   |
| <b>Interdendritic corrosion</b> | Corrosive attack that progresses preferentially along an interdendritic path [1].   |
| <b>Interface</b>                | Surface that forms the boundary between phases or systems, or both [1].   |
| <b>Intergranular corrosion</b>  | A preferential attack at the grain boundaries [2].  |
| <b>Intracrystalline</b>         | Within or across the crystals or grains of a metal, same as transcrystalline and transgranular [1].   |
| <b>Inverted microscope</b>      | A microscope so arranged that the line of sight is directed upwards through the objective to the object [2].  |
| <b>Ion etching</b>              | Surface removal by bombardment with accelerated ions in a vacuum (1 to 10 kV) [4].  |
| <b>Iron</b>                     | Iron-based metals not falling into the steel category, such as pure iron, gray iron, pig iron, white cast iron, etc. [3].   |
| <b>Isotropy</b>                 | The condition of having the same values of properties in all directions [2].  |
| <b>Kikuchi lines</b>            | Light and dark lines superimposed on the background of a single crystal electron diffraction pattern caused by diffraction of diffusely scattered electrons within the crystal [2].   |
| <b>Koehler illumination</b>     | A specular illumination system. In reflected-light microscopy, used directly for the brightfield mode, and as a preliminary setup for all other modes except darkfield. The image of the field diaphragm is focused on the specimen surface and the image of an undiffused lamp source is focused in the plane of the aperture diaphragm [2]. |
| <b>Knoop hardness</b>           | Microhardness determined from resistance of a metal to indentation using a rhombic-based pyramidal diamond indenter, which makes an impression with one long and one short diagonal [3].  |
| <b>Lamellar structure</b>       | A microstructure consisting of parallel plates of a second phase [3]. See <i>Pearlite</i> .   |
| <b>Laminate</b>                 | (1) A composite material, usually in the form of sheet or bar, composed of two or more materials bonded to form a solid structure. (2) Product of two or more bonded metal layers [3].  |
| <b>Lapping</b>                  | The abrasive removal of material using graded abrasive particles in a loose form as in a liquid slurry on a platen [2].   |
| <b>Lapping tracks</b>           | Indentations on the specimen surface made by abrasive particles moving freely on a hard surface. These are not scratches from a cutting action, but are the distinct tracks of particles tumbling over the surface without removing material [3].   |

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| <b>Light metal</b>                  | Low density metal such as aluminum, magnesium, titanium, beryllium, or their alloys [1].  |
| <b>Light microscopy</b>             | See <i>Optical microscope</i> .   |
| <b>Long-term etching</b>            | Etching times of a few minutes to several hours [4].  |
| <b>Lubricant</b>                    | Any substance used to reduce friction between surfaces in contact. Liquid used for cooling and lubricating. Depending on the type of material and the preparation stage, different types of lubricants can be used for grinding and polishing [3].  |
| <b>Machining</b>                    | Removing surface material in the form of chips, usually with a mechanical tool [3].   |
| <b>Macroetching</b>                 | Controlled etching of the surface of a metallic specimen, intended to reveal a structure which is visible at low magnifications (not usually greater than ten times) [2]. See also <i>Deep etching</i> .  |
| <b>Macroscopic</b>                  | Observation using the naked eye or magnifications up to 10–30 times [3].  |
| <b>Macrostructure</b>               | Structure of metals as revealed by macroscopic examination of the etched surface of a polished specimen [1].  |
| <b>Magnetic-particle inspection</b> | A nondestructive method of inspection for determining the existence and extent of possible defects in ferro-magnetic materials. On the surface of a magnetized part fine magnetic particles are attracted to areas where the magnetic field is displaced or interrupted, such as cracks or pores [1].   |
| <b>Malleability</b>                 | The characteristic of metals that permits plastic deformation in compression without rupture [1].   |
| <b>Malleable cast iron</b>          | A cast iron made by prolonged annealing of white cast iron in which decarburization or graphitization, or both, takes place to eliminate some or all of the cementite [1].  |
| <b>Martensite</b>                   | Metastable phase resulting from the diffusionless athermal decomposition of austenite below a certain temperature known as the $M_s$ temperature (martensite start temperature). It is produced during quenching when the cooling rate of a steel, in the austenitic condition, is such that the pearlite and bainite, or both, transformation is suppressed. The composition of the martensite is identical with that of the austenite from which it transformed. Hence, martensite is a super-saturated solid solution of carbon in alpha iron (ferrite) having a body-centered tetragonal lattice. It is a magnetic plate-like constituent formed by a diffusionless shear type of transformation. These plates may appear needle-like or veriform in cross section [2]. |



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| <b>Materialography</b>                            | Materialography is defined as an investigative method of materials science. It encompasses the optical examination of microstructures, and its goal is a qualitative and quantitative description of the microscopic structural analysis of solid materials. Materialography includes metallography, ceramography, plastography, and mineralogy [4]. See also <i>Metallography</i> . |
| <b>Matrix</b>                                     | The continuous phase [2]. See <i>Continuous phase</i> .  |
| <b>Mechanical polishing</b>                       | Specimen preparation process using finer and finer abrasives, mostly diamond, to obtain a surface suited for microscopic examination.  |
| <b>Mechanical properties</b>                      | The properties of a material that reveal its elastic and inelastic behavior when force is applied, by indicating its suitability for mechanical applications; for example, modulus of elasticity, tensile strength, elongation, hardness, and fatigue limit [1]. Compare with <i>Physical properties</i> .   |
| <b>Mechanical testing</b>                         | Determination of mechanical properties [1].  |
| <b>Mechanical twin</b>                            | A twin formed in a crystal by simple shear under external loading [1]. See also <i>Twin bands</i> .  |
| <b>Metallograph</b>                               | An optical instrument for the examination of metallographic/materialographic specimens. In principle it consists of a light source, a microscope, and a camera.  |
| <b>Metallography</b>                              | That branch of science which relates to the constitution and structure, and their relation to the properties, of metals and alloys [2]. See also <i>Materialography</i> .  |
| <b>Metallurgy</b>                                 | The science and technology of metals and alloys [1].   |
| <b>Metastable</b>                                 | A state of apparent equilibrium which has a higher free energy than has the true equilibrium state; usually applied to a phase existing outside its temperature and pressure span of equilibrium existence, by reason of a greatly delayed transformation [2].   |
| <b>Microetching</b>                               | Development of microstructure for microscopic observation. The usual magnification exceeds $25\times$ ( $50\times$ in Europe) [1].   |
| <b>Micrograph</b>                                 | A graphic reproduction of an object as seen through the microscope or equivalent optical instrument, at magnifications greater than ten diameters [2].   |
| <b>Micro indentation hardness (microhardness)</b> | Hardness of a material determined by forcing an indenter into the polished surface of a material under very light load using a microhardness tester [3]. See also <i>Micro penetration hardness</i> .  |
| <b>Micro penetration hardness</b>                 | The hardness number obtained by use of a low load tester whose indentation is usually measured with a high power microscope [2]. See also <i>Micro indentation hardness</i> .  |
| <b>Microscopy</b>                                 | The science of the interpretive use and applications of microscopes [1].   |

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| <b>Microstructure</b>              | The structure of a suitably prepared specimen as revealed by a microscope [2].   |
| <b>Mineralogy</b>                  | Scientific study of minerals [3]. See also <i>Petrographic examination</i> .   |
| <b>Modulus of elasticity (E)</b>   | The measure of rigidity or stiffness of a metal; the ratio of stress, below the proportional limit, to the corresponding strain. In terms of stress-strain diagram, the modulus of elasticity is the slope of the stress-strain curve in the range of linear proportionality of stress to strain. Also known as Young's modulus [1]. |
| <b>Monochromatic (homogeneous)</b> | Of the same wavelength [2].  |
| <b>Monocrystalline</b>             | A solid composed of a unique crystal [3].  |
| <b>Morphology</b>                  | The shape characteristics of a structure; the form and orientation of specific phase or constituent [2].   |
| <b>Mounting</b>                    | To embed the specimen in resin to facilitate the further handling during grinding and polishing, and to improve the preparation result [3].  |
| <b>Multiple etching</b>            | A specimen is etched sequentially with the specific etchants to reveal certain constituents [4].   |
| <b>Nitriding</b>                   | Nitriding is a form of surface hardening. By exposing a ferrous part at a certain temperature to nitrogenous materials, nitrogen will diffuse into the surface of the part and form hard nitrides [3].   |
| <b>Nitrocarburizing</b>            | Any of several case-hardening processes in which both nitrogen and carbon are absorbed into the surface layers of a ferrous material at a certain temperature. Nitrocarburizing improves fatigue resistance [1].   |
| <b>Noble metal</b>                 | (1) A metal whose potential is highly positive relative to the hydrogen electrode. (2) A metal with marked resistance to chemical reaction, particularly to oxidation and to solution by inorganic acids. The term as often used is synonymous with precious metal [1].  |
| <b>Nodular cast iron</b>           | Also called ductile cast iron; trace amounts of magnesium are added to the melt to induce formation of free graphite in the form of nodules. See also <i>Spheroidal cast iron</i> .  |
| <b>Nonmetallic inclusions</b>      | Particles of impurities (usually oxides, sulfides, silicates, and such) that are held mechanically or are formed during solidification or by subsequent reaction within the solid metal [2]. See also <i>Exogenous inclusions</i> , <i>Inclusions</i> .  |
| <b>Nondestructive testing</b>      | Inspection by methods that do not destroy the part in order to determine its suitability for use [1]. See also <i>Field metallography</i> .  |
| <b>Normalizing</b>                 | Heating a ferrous alloy to a suitable temperature above the transformation range and then cooling it in air to a temperature substantially below the transformation range [1].   |

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| <b>Numerical aperture (NA)</b> | The sine of half the angular aperture of an objective lens multiplied by the refractive index of the medium between the lens and the sample [2].  |
| <b>Objective</b>               | The primary magnifying system of a microscope [1].  |
| <b>Ocular</b>                  | See <i>Eyepiece</i> .   |
| <b>Optical etching</b>         | Develops the microstructure by using special illumination techniques (dark field, interference contrast, polarized light, phase contrast) [4].  |
| <b>Optical microscope</b>      | Instrument containing one or more lenses which uses artificial light to produce an enlarged image of an object placed in the focal plane of the lens(es) [3].   |
| <b>Ore</b>                     | A natural mineral that may be mined and treated for the extraction of any of its components, metallic or otherwise [3].   |
| <b>Organic materials</b>       | For example, wood, bone, tissue, teeth, paper.  |
| <b>Orientation</b>             | The angular position of a crystal described by the angles which certain crystallographic axes make with the frame of reference. In hardness measurements, the relationship between the direction of the axes of the indenter of a hardness tester and the direction of nonhomogeneous properties of the specimen [2].   |
| <b>Overheating</b>             | (1) In ferrous alloys, heating to an excessively high temperature such that the properties/structure undergo modification. The resulting structure is very coarse-grained. Unlike burning, it may be possible to restore the original properties/structure by further heat treatment or mechanical working, or a combination thereof. (2) In aluminum alloys, overheating produces structures that show areas of resolidified eutectic or other evidence that indicates the metal has been heated within the melting range [2]. |
| <b>Oxide polishing</b>         | Process used for the final polishing of a specimen with a suspension containing fine abrasive particles of oxides (aluminum oxide, silicon dioxide) with or without chemicals of different pH. See also <i>Final polishing</i> .  |
| <b>Oxidation</b>               | (1) A reaction in which there is an increase in valence resulting from a loss of electrons. (2) A corrosion reaction in which the corroded metal forms an oxide; usually applied to reaction with a gas containing elemental oxygen, such as air [1].   |
| <b>P</b>                       | Polishing (mechanical) taking place as the last steps (P1, P2, P3, etc.) of metallographic/materialographic preparation to obtain a surface suited for microscopic examination. See also <i>Final polishing</i> , <i>Oxide polishing</i> , <i>Polishing</i> .   |
| <b>Particle size</b>           | The controlling linear dimension of an individual particle, such as of a powdered metal, as determined by analysis with screens or other suitable instruments [1].  |

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| <b>Pearlite</b>                  | A metastable microstructure formed when local austenite areas attain the eutectoid composition in alloys of iron and carbon containing greater than 0.025 % but less than 6.67 % carbon. The structure is an aggregate consisting of alternate lamellae of ferrite and cementite formed on slow cooling during the eutectoid reaction. In an alloy of given composition, pearlite may be formed isothermally at temperatures below the eutectoid temperature by quenching austenite to a desired temperature (generally above 550°C) and holding for a period of time necessary for transformation to occur. The interlamellar spacing varies directly with the transformation temperature; that is, the higher the temperature the greater the spacing [2]. |
| <b>Petrographic examination</b>  | Methods of examining nonmetallic matter under suitable microscopes to determine structural relationships and to identify the phases or minerals present. With transparent materials, the determination of the optical properties, such as the indices of refraction and the behavior in transmitted polarized light, serve as means of identification. With opaque materials, the color, hardness, reflectivity, shape, and etching behavior in polished sections serve as means of identification. Metallographic applications include examination of particles mechanically or chemically separated from the metal by these methods [2].   |
| <b>PG</b>                        | Plane (planar) grinding. Removes damage introduced by cutting, and levels specimens clamped in a holder for automatic grinding [3]. See also <i>Planar grinding</i> .  |
| <b>pH</b>                        | The negative logarithm of the hydrogen-ion activity. It denotes the degree of acidity or basicity of a solution. At 25°C (77°F), 7.0 is the neutral value. Lower values than 7.0 indicate acidity and higher values increasing basicity [1].   |
| <b>Phase</b>                     | A physically homogeneous and distinct portion of a material system [1].  |
| <b>Phase contrast microscopy</b> | A special method of controlled illumination, ideally suited for observing thin, transparent objects whose structural details vary only slightly in thickness or refractive index. This can also be applied to the examination of opaque materials to determine surface elevation changes [2].  |
| <b>Photo micrograph</b>          | See <i>Micrograph</i> .  |
| <b>Physical etching</b>          | Develops the microstructure through removal of surface atoms, lowering the grain surface potential and deposition of interference layers [4].  |
| <b>Physical properties</b>       | Properties, other than mechanical properties, that pertain to the physical nature of a material; for example, density, electrical conductivity, thermal expansion, reflectivity, magnetic susceptibility, and so on [1]. See also <i>Mechanical properties</i> .   |

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| <b>Physical testing</b>             | Determination of physical properties [1].   |
| <b>Pig</b>                          | Metal casting poured from the melting furnace, used for remelting [3].  |
| <b>Pitting</b>                      | Forming small sharp cavities in a metal surface if electrolytic polishing is not performed correctly.   |
| <b>(metallography)</b>              |   |
| <b>Pixel (picture element)</b>      | Smallest spatial unit of an image [2].  |
| <b>Planar grinding</b>              | The first step in a preparation procedure used to bring all specimens into the same plane of polish. It is unique to semi or fully automatic preparation equipment that utilize specimen holders [2]. See also <i>PG</i> .  |
| <b>Plane grinding</b>               | See <i>PG</i> .   |
| <b>Plasma spraying</b>              | Coating technique in which the coating material is fed as powder into an ionized gas atmosphere (plasma) and sprayed in the molten state onto the surface to be coated [3].   |
| <b>Plastic</b>                      | Any of various organic compounds produced by polymerization, capable of being molded, extruded, cast into various shapes and films, or drawn into filaments used as textile fibers [3].   |
| <b>Plastic deformation</b>          | Deformation that remains or will remain permanent after release of the stress that caused it [1].   |
| <b>Plasticity</b>                   | The capacity of a material to deform nonelastically without rupturing [1].  |
| <b>Plating</b>                      | Forming an adherent layer of metal on metal, usually through a galvanic process. Any adherent layer of metal on other material can also be called plating [3].  |
| <b>Plowing</b>                      | In tribology, the formation of grooves by plastic deformation of the softer of two surfaces in relative motion [1].   |
| <b>Polarized light illumination</b> | A method of illumination in which the incident light is plane polarized before it impinges on the specimen [2].   |
| <b>Polishing</b>                    | A mechanical, chemical, or electrolytic process or combination thereof used to prepare a smooth reflective surface suitable for microstructure examination, free of artifacts or damage introduced during prior sectioning or grinding [2]. See also <i>Final polishing</i> , <i>Oxide polishing</i> , <i>Polishing cloth</i> . |
| <b>Polishing artifact</b>           | A false structure introduced during a polishing stage of a surface preparation sequence [1]. See also <i>Artifact</i> .   |
| <b>Polishing cloth</b>              | A substrate, mostly a textile or a nonwoven material, used for polishing of specimens with selected abrasives. See also <i>Final polishing</i> , <i>Oxide polishing</i> , <i>Polishing</i> .  |
| <b>Polishing rate</b>               | The rate of which material is removed from a surface during polishing. It is usually expressed in terms of the thickness removed per unit of time or distance traversed [1].  |
| <b>Polycrystalline</b>              | Characteristic of an aggregate composed of more than one, and usually of a large number, of crystals [2].   |

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| <b>Polymers</b>                   | Plastics, for instance polyethylene, epoxy, polyester and polyacryl, and polyamide (Nylon) [3].   |
| <b>Pores</b>                      | Small voids in the body of a material [1].  |
| <b>Porosity</b>                   | Holes in a solid, not necessarily connected [2].  |
| <b>Potentiostatic etching</b>     | Anodic development of the microstructure at a constant potential enables a defined etching of singular phases [4].  |
| <b>Powder</b>                     | Particles of a solid characterized by small size, nominally within the range from 0.1 to 1000 $\mu\text{m}$ [3].  |
| <b>Powder metallurgy</b>          | Production and use of metal powders, which are hot pressed and sintered into solid materials and shaped objects [1].  |
| <b>Precious metals</b>            | Gold, silver, and platinum-group metals [3].  |
| <b>Precipitation</b>              | Separation of a new phase from solid, liquid, or gaseous solutions, usually with changing conditions of temperature or pressure, or both [2].   |
| <b>Precipitation etching</b>      | Develops the microstructure by the formation of reaction products at the specimen surface [4].  |
| <b>Precipitation hardening</b>    | Hardening caused by precipitation of a constituent from a supersaturated solid solution [1]. See also <i>Age hardening</i> , <i>Aging</i> .   |
| <b>Primary crystals</b>           | The first type of crystals that separates from a melt on cooling [2].   |
| <b>Primary etching</b>            | Develops the cast microstructures including coring [4]. See also <i>Secondary etching</i> .   |
| <b>Pull-out</b>                   | Void existing on the plane of polish of a metallographic specimen caused by the dislodging of a particle or constituent during the grinding or polishing operation [2].   |
| <b>Quantitative metallography</b> | Determination of specific characteristics of a microstructure by making quantitative measurements on micrographs or metallographic/materialographic images. Quantities so measured include volume concentration of phases, grain size, particle size, and surface-area-to-volume ratios of micro-constituents, particles, or grains [1]. See also <i>Automatic image analysis</i> . |
| <b>Quenching</b>                  | Rapid cooling, usually in water [3].  |
| <b>Quenching crack</b>            | A crack formed as a result of thermal stresses produced by rapid cooling from a high temperature, not to be confused with fire crack [2].   |
| <b>Ram</b>                        | Moving part in e.g. the cylinder of a mounting press [3].   |
| <b>Rare earth metals</b>          | One of the group of 15 chemically similar metals with atomic numbers 57 through 71, commonly referred to as the lanthanides [1].  |
| <b>RCD</b>                        | Rigid composite disk, hard or soft, used for fine grinding. See also <i>Rigid grinding disk</i> .   |
| <b>Recarburize</b>                | (1) Increase the carbon content of molten cast iron or steel by adding carbonaceous material, high-carbon pig iron or a high carbon alloy. (2) Carburize a metal part to return surface carbon loss in processing [1].  |

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| <b>Recrystallization</b> | The formation of a new grain structure through nucleation and growth commonly produced by subjecting a metal, that may be strained, to suitable conditions of time and temperature [3].                     |
| <b>Reflected light</b>   | In the metallographic/materialographic microscope the specimen is illuminated with reflected (incident) light. For examination of mineralogical thin sections and in biology the transmitted light is used. |
| <b>Refractory</b>        | (1) Material of very high melting point with properties that make it suitable for furnace linings and kiln construction. (2) Quality of resisting heat [1].   |
| <b>Refractory alloy</b>  | (1) Heat-resistant alloy. (2) Alloy having an extremely high melting point. (3) An alloy difficult to work at elevated temperatures [1].  |
| <b>Refractory metal</b>  | Metal with an extremely high melting point, above the range of iron, cobalt, and nickel (Mo, V, W, Ta, Nb) [3].   |
| <b>Relief</b>            | Due to varying hardness or wear rate of a matrix or individual phases, or both; material is removed at different rates, and relief is developed [3].  |
| <b>Removal rate</b>      | The rate at which material is removed from a surface during grinding and polishing. See also <i>Polishing rate</i> .  |

**Replica**

A reproduction of a surface in a material, for example, a plastic.

(1) Atomic. A thin replica devoid of structure on the molecular level, prepared by the vacuum or hydrolytic deposition of metals or simple compounds of low molecular weight.

(2) Cast. A reproduction of a surface in plastic made by the evaporation of the solvent from a solution of the plastic or by polymerization of a monomer on the surface.

(3) Collodion. A replica of a surface cast in nitro-cellulose.

(4) Formvar. A reproduction of a surface in a plastic Formvar film.

(5) Gelatin. A reproduction of a surface prepared in a film composed of gelatin.

(6) Impression. A surface replica which is made by impression. The results of making an impression.

(7) Molecular. The reproduction of a surface in a high polymer such as collodion and other plastics.

(8) Negative. That replica which is obtained by the direct contact of the replicating material with the specimen. In it, the contour of the replica surface is reversed with respect to that of the original.

(9) Oxide film. A thin film of an oxide of the specimen to be examined. The replica is prepared by air, oxygen, chemical, or electrochemical oxidation of the parent metal and is subsequently freed either mechanically or chemically for purposes of examination.

(10) Plastic. A reproduction in plastic of the surface to be studied, prepared by evaporation of the solvent from a solution of plastic, by polymerization of a monomer, or solidification of a plastic on the surface.

(11) Positive. A replica, the contours of which correspond directly to the surface being replicated; that is, elevations on the surface are elevations on the replica.

(12) Preshadowed. A replica formed by the application of the shadowing material to a surface to be replicated, before the thin replica film is cast or otherwise deposited on the surface.

(13) Pseudo. A replica which has portions of the material being replicated embedded in it.

(14) Tape replica method (faxfilm). A method of producing a replica by pressing the softened surface of a tape or sheet of a plastic material on the surface to be replicated.

(15) Vapor deposited—a replica formed of a metal or a salt by the condensation of the vapors of the material onto the surface to be replicated [2].



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| <b>Reproducibility</b>        | The ability to achieve the same result every time. In specimen preparation reproducibility is crucial, as specimen preparation is often employed in quality inspection and failure analysis. Reproducibility can be ensured by using consumables of high standard and uniform quality, and by using automatic preparation equipment which controls preparation parameters, e.g., rotational speed, force, dosing levels, and time [3].  |
| <b>Resolution</b>             | <p>The fineness of detail in an object which is revealed by an optical device. Resolution is usually specified as the minimum distance by which two lines or points in the object must be separated before they can be revealed as separate lines or points in the image. The theoretical limit of resolution is determined from the equation:</p> $d = 0.61\lambda/(n \sin A.A./2)$ <p>where</p> <p><math>d</math> = minimum distance between object points observed as distinct points in the image;</p> <p><math>\lambda</math> = wavelength of the radiation employed;</p> <p><math>n</math> = the minimum refractive index of the media between the object and the objective lens;</p> <p><math>A.A.</math> = the angular aperture [2]. See also <i>Resolving power</i>.</p> |
| <b>Resolving power</b>        | The ability of a given lens system to reveal fine detail in an object [2]. See also <i>Resolution</i> .   |
| <b>Reticle</b>                | A system of lines, circles, dots, cross hair or wires, or some other pattern, placed in the eyepiece or an intermediate plane on the optic axis which is used as a measuring reference, focusing target, or to define a camera field of view (a reticle is different than a graticule) [2]. See also <i>Graticule</i> .   |
| <b>Rigid grinding disk</b>    | A nonfabric support surface, such as a composite of metal/ceramic or metal/polymer, charged during use with an abrasive (usually 6 to 15 micrometre diamond particles) and used for grinding operations in a metallographic preparation [2]. See also <i>RCD</i> .  |
| <b>Rockwell hardness test</b> | Indentation hardness test based on the depth of penetration of a specified penetrator (cone or ball) into a specimen under a specified load [3].  |
| <b>Roughness</b>              | Relatively finely spaced surface irregularities, the heights, width, and directions of which establish the predominant surface pattern [1].   |

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| <b>Rough polishing</b>              | A polishing process after fine grinding to remove the layer of significant damage caused by the grinding. Rough polishing is followed by the steps polishing and final polishing to finish the specimen preparation. See also <i>Final polishing</i> , <i>Oxide polishing</i> , <i>Polishing</i> .   |
| <b>Scanning microscope</b>          | An electron microscope in which the image is formed by a beam operating in synchronism with an electron probe scanning the object. The intensity of the image forming beam is proportional to the scattering or secondary emission of the specimen where the probe strikes it [2]. See also <i>SEM</i> .   |
| <b>Scratches</b>                    | A groove produced in a surface by an abrasive point [1].   |
| <b>Secondary etching</b>            | Develops the microstructures that differ from primary structures through transformation and heat treatment in the solid state [4]. See also <i>Primary etching</i> .   |
| <b>Segregation</b>                  | Concentration of alloying elements in specific regions in a metallic object [2].   |
| <b>Segregation (coring) etching</b> | Develops segregation (coring) mainly in macrostructures and microstructures of castings [4].   |
| <b>SEM</b>                          | Scanning Electron Microscope is a type of electron microscope capable of producing high resolution images of a specimen surface. Due to the manner in which the image is created, SEM images have a characteristic three-dimensional appearance and are useful for judging the surface structure of the specimen [3]. See also <i>Scanning microscope</i> .  |
| <b>SG iron</b>                      | See <i>Ductile cast iron</i> .   |
| <b>Shear</b>                        | (1) That type of force that causes or tends to cause two contiguous parts of the same body to slide relative to each other in a direction parallel to their plane of contact. (2) A type of cutting tool with which a material in the form of wire, sheet, plate, or rod is cut between two opposing blades. (3) The type of cutting action produced by rake so that the direction of chip flow is other than at right angles to the cutting edge [1]. |
| <b>Short-term etching</b>           | Etching time of seconds to a few minutes [4].  |
| <b>Shrinkage</b>                    | Reduction in volume of a material from beginning to end of solidification [3].   |
| <b>Shrinkage cavity</b>             | A void left in cast metals as a result of solidification shrinkage [1].  |
| <b>Shrinkage gaps</b>               | Gaps are voids between the mounting resin and sample material caused by shrinkage of the mounting resin [3].   |
| <b>Single specimen</b>              | Single specimens can be prepared on preparation systems using specimen mover plates. The specimens are not clamped and force is applied to each individual specimen [3].   |

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| <b>Sintering</b>                                       | Bonding of particles in a mass of metal powder by heating, usually with prior compacting [3].  |
| <b>Slag</b>  | Nonmetallic product resulting from the dissolution of flux and nonmetallic impurities in smelting, refining, and certain welding operations [1]. See also <i>Inclusions</i> .  |
| <b>Slip</b>  | Translation of a portion of a crystal relative to the adjacent portion [2].  |
| <b>Slip lines</b>                                      | Traces of slip planes observed at low magnifications on the polished surface of a crystal which has been deformed after polishing; since no differences in orientation exist, repolishing will remove the traces. With increasing resolving power and magnification, an individual line may be revealed as a series of parallel lines. The “line” which is visible at low magnifications is then described as a slip band [2]. |
| <b>Smearing</b>  | Plastic deformation of a soft matrix or soft phases. Instead of being cut, the material is pushed, moved across the surface. Smearing occurs when the abrasive is too small or when using the wrong lubricant or polishing cloth, or a combination of these conditions, which reduces the cutting effect of the abrasive [3].  |
| <b>Soldering</b>                                       | Bonding of metals using filler metals at temperatures below 450°C [3].   |
| <b>Specimen</b>  | A test object, often of standard dimensions or configuration, or both, which is used for destructive and nondestructive testing. One or more specimens may be cut from each unit of a sample [1].  |
| <b>Specimen holder (metallography/materialography)</b> | A holder in which 3–12 specimens are clamped. During specimen preparation force is applied to the center of the holder [3].  |
| <b>Spheroidal cast iron (SG)</b>                       | Same as nodular cast iron or ductile cast iron. See also <i>Nodular cast iron</i> .  |
| <b>Spheroidite</b>                                     | A coarse aggregate of carbide and ferrite usually produced by tempering martensite at temperatures slightly below the eutectoid temperature. Generally, any aggregate of ferrite and large spheroidal carbide particles no matter how produced [2].  |
| <b>Spheroidizing</b>                                   | Heating and cooling to produce a spheroidizing or globular form of carbide in steel [1].   |
| <b>Stage</b>   | A device for holding a specimen in the desired position in the optical path [2].   |
| <b>Stage micrometre</b>                                | A graduated scale used on the stage of a microscope for calibration [2].   |
| <b>Staining</b>  | Staining is a discoloration of the specimen surface, typically caused by water, alcohol, or etching solutions [3].   |

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| <b>Stainless steel</b>    | Any of several steels containing 12 to 30 % chromium as the principal alloying element [1].  |
| <b>Steel</b>              | Malleable iron-base alloy, containing carbon and other alloying elements. Carbon and low-alloy steels contain a maximum of 2 % carbon, high-alloy steels up to 2.5 % carbon and over 8 % metallic alloying elements [3].   |
| <b>Stereology</b>         | The study of mathematical procedures used to derive three-dimensional parameters describing a structure from two-dimensional measurement [2].  |
| <b>Stereomicroscope</b>   | A light optical microscope that permits each eye to examine the specimen at a slightly different angle, thereby retaining its three-dimensional relationship [2].  |
| <b>Strain hardening</b>   | An increase in hardness and strength caused by plastic deformation at temperatures below the recrystallization range [1].  |
| <b>Stringer</b>           | A single, high-aspect ratio, elongated inclusion, two or more elongated inclusions, or a number of small nondeformable inclusions aligned in a linear pattern due to deformation [2]. See also <i>Inclusions</i> .   |
| <b>Structure</b>          | As applied to a crystal, the shape and size of the unit cell and the location of all atoms within the unit cell. As applied to microstructure, the size, shape, and arrangement of phases [2]. See also <i>True structure</i> , <i>Polishing</i> .   |
| <b>Subgrain</b>           | A portion of a crystal or grain, with an orientation slightly different from the orientation of neighboring portions of the same crystal or grain [1].   |
| <b>Substrate</b>          | (Substratum) that which lies under [2].  |
| <b>Superalloy</b>         | Same as heat-resistant alloy; superalloys are heat and corrosion resistant and ductile and contain up to 20 % chromium (Cr) [3]. See also <i>Heat-resistant alloy</i> .  |
| <b>Swab etching</b>       | Wiping the specimen surface with cotton saturated with an etchant. This will simultaneously remove undesired reaction products [4].  |
| <b>Swarf</b>              | Mixture of chips, abrasive material, and lubricating medium developing during grinding/polishing.  |
| <b>Technical ceramics</b> | Pressed and sintered oxides, carbides, and nitrides. They are very dense, insulators, highly wear resistant, and resistant against chemicals: aluminum oxide ( $\text{Al}_2\text{O}_3$ ), silicon carbide (SiC), silicon nitride ( $\text{Si}_3\text{N}_4$ ), tungsten carbide (WC), titanium carbide (TiC), boron carbide ( $\text{B}_4\text{C}$ ), titanium boride ( $\text{TiB}_2$ ), zirconium oxide ( $\text{ZrO}_2$ ) [3]. |

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| <b>TEM</b>                     | The Transmission Electron Microscope is an imaging instrument whereby a beam of electrons is focused onto a specimen causing an enlarged version to appear on a fluorescent screen or layer of photographic film or can be detected by a CCD camera [3]. See also <i>Thin foil</i> , <i>Transmission microscope</i> .  |
| <b>Tensile testing</b>         | To determine the strength of a material by pulling a sample applying equal and constant stress until it breaks. The elongation of the sample is also measured. Also known as tension testing [3].  |
| <b>Thermal</b>                 | Any physical process taking place due to heat [3].   |
| <b>Thermal etching</b>         | Annealing the specimen in a vacuum or inert atmosphere. This is a preferred technique for high-temperature microscopy and for ceramics [4].  |
| <b>Thermoplastic resins</b>    | Mounting resins that soften or melt at elevated temperatures and harden during cooling [3].  |
| <b>Thermosetting resins</b>    | Mounting resins that cure under heat and pressure and cannot be melted after curing. They are also called duroplastics [3].  |
| <b>Thin foil</b>               | A very thin specimen prepared for transmission microscopy. See also <i>TEM</i> .   |
| <b>Tool steel</b>              | Any of a class of carbon and alloy steels commonly used to make tools. Tool steels are characterized by high hardness and resistance to abrasion, often accompanied by high toughness and resistance to softening at elevated temperature. These attributes are generally attained with medium carbon and high-alloy contents [1].   |
| <b>Traditional ceramics</b>    | Earthenware, brick, clay, porcelain [3].   |
| <b>Transmission microscope</b> | A microscope in which the image forming rays pass through (are transmitted by) the specimen being observed [2]. See also <i>TEM</i> .  |
| <b>True structure</b>          | The microstructure representing the material without any influences from the preparation of the specimen. See also <i>Structure</i> , <i>Polishing</i> .   |
| <b>Twin bands</b>              | Bands across a crystal grain, observed on a polished and etched section, the crystallographic orientations of which have a mirror image relationship to the orientation of the matrix grain across a composition plane which usually is parallel to the sides of the band. (1) Annealing twins—twin bands which are produced during annealing following cold work. (2) Mechanical twins—twin bands which are produced by cold work. (3) Neumann bands—mechanical twins in ferrite [2]. |
| <b>Ultrasonic cleaning</b>     | Immersion cleaning aided by ultrasonic waves that cause microagitation [1].  |

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| <b>Ultrasonic testing</b>    | Nondestructive test used on sound conductive materials to locate cavities, cracks, and structural discontinuities by means of ultrasonic impulse [3].  |
| <b>Vibratory polishing</b>   | Mechanical polishing process where one or several specimens are moved around in a bowl through vibration of the bottom of the bowl.  |
| <b>Vickers</b>               | In a more restricted sense, the 136° diamond pyramid indenter used in microindentation hardness tests [2]. See also <i>Micro indentation hardness</i> , <i>Micro penetration hardness</i> , <i>Vickers hardness test</i> .   |
| <b>Vickers hardness test</b> | Indentation hardness test using a pyramid-shaped diamond indenter and variable loads which enables the use of one hardness scale for all materials from very soft lead to tungsten carbide [3]. See also <i>Micro indentation hardness</i> , <i>Micro penetration hardness</i> , <i>Vickers</i> .                |
| <b>Weld</b>                  | Union between materials by welding [3]. See also <i>Welding</i> .  |
| <b>Welding</b>               | Joining two or more pieces of metal by applying heat or pressure, or both, with or without a filler material, to produce a localized union through fusion or recrystallization across the interface [1].   |
| <b>Weld structure</b>        | The microstructure of a weld deposit and heat-affected base metal [2]. See also <i>Welding</i> .   |
| <b>Wet etching</b>           | The specimen surface has to be wetted before immersion into the etching solution. This is important for color etchants [4].  |
| <b>Whiskers</b>              | Metallic or ceramic filaments, mostly microscopic, more or less evenly distributed in a matrix [3].  |
| <b>White cast iron</b>       | Cast iron that shows a white fracture because the carbon is present in the form of iron carbide, $\text{Fe}_3\text{C}$ , which gives it its very high hardness and also brittleness [3].   |
| <b>White metal</b>           | A general term covering a group of white-colored metals and their alloys of relatively low melting points (lead, antimony, tin, cadmium, bismuth, and zinc) and alloys based on these metals [1].  |
| <b>Wire cutting</b>          | A cutting method mainly used for sectioning of small specimens of various types of materials. A fine wire is drawn along the work piece with a controlled force. The abrasive is either diamond bonded to the wire, or an abrasive slurry that is dripped continuously onto the wire and drawn into the cut [3]. |
| <b>Workability</b>           | See <i>Formability</i> .   |
| <b>Work hardening</b>        | A change in the hardness of a material as a result of plastic deformation [2].   |
| <b>Working distance</b>      | The distance between the surface of the specimen being examined and the front surface of the objective lens [2].   |

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| <b>Wrought iron</b>    | An iron produced by direct reduction of ore or by refining molten cast iron under conditions where a pasty mass of solid iron with included slag is produced. The iron has a low carbon content [1]. |
| <b>X-ray testing</b>   | Using X-ray radiation to check work pieces for cavities, cracks, pores, and overlaps. Especially used for checking of welds [3].   |
| <b>Young's modulus</b> | A term used synonymously with modulus of elasticity. The ratio of tensile or compressive stresses to the resulting strain [1]. See also <i>Modulus of elasticity</i> .                               |

### References (Glossary)

- [1] Benscoter, A. O. and Bramfitt, B. L., *Metallographer's Guide, Practices and Procedures for Irons and Steels*, ASM International, Materials Park, Ohio, USA, 2002. Reprinted with permission of ASM International®. All rights reserved. [www.asminternational.org](http://www.asminternational.org)
- [2] ASTM Standard, *Terminology Relating to Metallography (E 7)*, ASTM International, West Conshohocken, Pennsylvania, USA, 2003.
- [3] Terms defined by Struers in the on-line training material e-Education and e-Training under [www.struers.com](http://www.struers.com).
- [4] Petzow, G., *Metallographic Etching*, ASM International, Materials Park, Ohio, USA, 1999.