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Standard Terminology Relating to Metallography[1]

This standard is issued under the fixed designation E7; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope

1.1 This standard covers the definition of terms, acronyms, and symbols used in ASTM documents related to the field of metallography and metallographic testing. Terms that are only relevant to a particular standard or that are adequately defined in a general dictionary are not defined in this terminology standard.

1.2 This standard includes terminology used in metallographic areas, such as, but not limited to: light microscopy, microindentation hardness testing, specimen preparation, x-ray and electron metallography, quantitative metallography, photomicrography, and determination of grain size and inclusion content.

1.3 This standard may be of use to individuals utilizing standards of Committee E04 as well as by those in need of a general reference source for terminology in the field of metallography.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E45 Test Methods for Determining the Inclusion Content of Steel

E80 Recommended Practice for Dilatometric Analysis of Metallic Materials; Replaced by E 228 (Withdrawn 1986)[3]

E112 Test Methods for Determining Average Grain Size

E1122 Practice for Obtaining JK Inclusion Ratings Using Automatic Image Analysis (Withdrawn 2006)[3]

3. Significance and Use

3.1 Standards of Committee E04 consist of test methods, practices, and guides developed to ensure proper and uniform testing in the field of metallography. In order for one to properly use and interpret these standards, the terminology used in these standards must be understood.

3.2 The terms used in the field of metallography have precise definitions. The terminology and its proper usage must be completely understood in order to adequately communicate in this field. In this respect, this standard is also a general source of terminology relating to the field of metallography facilitating the transfer of information within the field.

4. Terminology

absorption—the decrease in intensity which radiation undergoes during its passage through matter when the ratio of transmitted or reflected luminous flux to incident is less than 1.

absorption coefficient—specific factor characteristic of a substance on which its absorption radiation depends. The rate of decrease of the natural logarithm of the intensity of a parallel beam per unit distance traversed in a substance. For X-rays, the linear absorption coefficient is the natural logarithm of the ratio of the incident intensity of an X-ray beam incident on unit thickness of an absorbing material to the intensity of the beam transmitted. If I_e is the incident intensity of a beam of X-rays, I_t the transmitted intensity, and X the thickness of the absorbing material, then:

$$I_t = I_e exp(-\mu X) \quad (1)$$

Here μ is the linear absorption coefficient. The mass absorption coefficient is given by μ/ρ where ρ is the density.

absorption edge—an abrupt change in absorption coefficient at a particular wavelength. The absorption coefficient is always larger on the short wavelength side of the absorption edge.

absorption limit—See **absorption edge.**

accelerating potential—a relatively high voltage applied between the cathode and anode of an electron gun to accelerate electrons.

achromatic—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. See **apochromatic objective**

[1] This terminology is under the jurisdiction of ASTM Committee E04 on Metallography and are the direct responsibility of Subcommittee E04.02 on Terminology.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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

achromatic objective—an objective that is corrected chromatically for two colors, and spherically for one, usually in the yellow-green part of the spectrum.

achromatic objective lens—an objective lens with longitudinal chromatic correction for green and blue, and spherical chromatic correction for green. Note—Lens should be used with a green filter.

acid extraction—See **extraction.**

air-lock—an intermediate enclosed chamber of a vacuum or pressure system through which an object may be passed without materially changing the vacuum or pressure of the system.

alignment—a mechanical or electrical adjustment of the components of an optical device in such a way that the path of the radiating beam coincides with the optical axis or other predetermined path in the system. In electron optics there are three general types:

(*1*) *magnetic alignment*—an alignment of the electron optical axis of the electron microscope such that the image rotates about a point in the center of the viewing screen when the current flowing through a lens is varied.

(*2*) *mechanical alignment*—a method of aligning the geometrical axis of the electron microscope by relative physical movement of the components, usually as a step preceding either magnetic or voltage alignment.

(*3*) *voltage alignment*—a condition of alignment of an electron microscope such that the image expands or contracts symmetrically about the center of the viewing screen when the accelerating voltage is changed.

allotriomorphic crystal—a crystal whose lattice structure is normal, but whose outward shape is imperfect since it is determined to some extent by the surroundings; the grains in a metallic aggregate are allotriomorphic crystals.

alloy system—a complete series of compositions produced by mixing in all proportions any group of two, or more, components, at least one of which is a metal.

alpha brass—a solid solution phase of one or more alloying elements in copper and having the same crystal lattice as copper.

alpha iron (Fe)—solid phase of pure iron which is stable at temperatures below 910°C and possesses the body-centered cubic lattice. It is ferro-magnetic below 768°C.

amplifier—a negative lens, used in lieu of an eyepiece, to project under magnification the image formed by an objective. The amplifier is especially designed for flatness of field and should be used with an apochromatic objective.

ampliphan eyepiece— See **amplifier.**

analyzer—an optical device, capable of producing plane polarized light, used for detecting the state of polarization.

angle of reflection: (*1*) *reflection* —the angle between the reflected beam and the normal to the reflecting surface.

(*2*) *diffraction*—the angle between the diffracted beam and the diffracting planes.

Angstrom unit (abbreviation) = A,Å , or *A. U*—a unit of length equal to 10^{-8} cm. This is the standard unit of measurement in X-ray crystallography.

angular aperture—See **aperture, optical.**

anisotropic (replaces anisotropy)—having different values for a property, in different directions.

annealing-twin bands— See **twin bands.**

anode aperture—See **aperture.**

anvil—the base on which objects for hardness test are placed.

anvil effect—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 under side of the specimen.

aperture, electron:—

anode aperture— the opening in the accelerating voltage anode shield of the electron gun through which the electrons must pass to illuminate or irradiate the specimen.

condenser aperture—an opening in the condenser lens controlling the number of electrons entering the lens and the angular aperture of the illuminating beam. The angular aperture can also be controlled by the condenser lens current.

physical objective aperture—a metal diaphragm, centrally pierced with a small hole, used to limit the cone of electrons accepted by the objective lens. This improves image contrast since highly scattered electrons are prevented from arriving at the Gaussian image plane and therefore can not contribute to background fog.

aperture, optical—the working diameter of a lens or a mirror.

angular aperture— the angle between the most divergent rays which can pass through a lens to form the image of an object.

aperture diaphragm—a device to define the aperture.

apochromatic objective—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.

arcing—in electron diffraction, the production of segments of circular patterns, indicating a departure from completely random orientation of the crystals of the specimen.

arrest—that portion of a cooling curve in which temperature is invariant with time (for example, thermal or eutectic arrest).

artifact—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.

ascending fork point—in a ternary phase diagram, the configuration at the convergence of the three bivariant curves upon each of the four phases associated in Class II univariant equilibrium; for example, the union of two ascending liquidus surface valleys to form one ascending liquidus surface valley.

aspect ratio—the length-to-width ratio of a microstructural feature in a two-dimensional plane.

asterism—a lengthening of diffraction spots usually in the radial direction.

astigmatism—a defect in a lens or optical system which causes rays in one plane parallel to the optical axis to focus at a distance different from those in the plane at right angles to it.

ASTM grain size number— See **grain size.**

athermal—not isothermal, with changing rather than constant temperature conditions.

atomic replica—See **replica.**

atomic scattering factor—the ratio of the amplitude of the wave scattered by an atom to that scattered by a single electron. Symbol = *f*.

austenite—a face-centered cubic solid solution of carbon or other elements in gamma iron.

austenite grain size—the grain size which exists or existed in austenite at a given temperature. See Test Methods E112.

autographic dilatometer—a dilatometer that automatically records instantaneous and continuous changes in dimensions and some other controlled variable such as temperature or time.

autographic pyrometer— See **pyrometer.**

automatic image analysis—the separation and quantitative evaluation of an image into its elements with or without operator interaction. It includes the enhancement, detection, and quantification of the features contained in an image through the use of optical, geometrical, and stereological parameters and a computer program. Image analysis data output can provide individual measurements on each separate feature (feature specific) or totals for all features of a particular type in the field (field specific).

automatic image analyzer—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.

average coefficient of cubical expansion— average change in unit volume of a substance per unit change in temperature over a specified range of temperature.

average coefficient of linear expansion— average change in unit length of a body per unit change in temperature over a specified range of temperature.

average coefficient of thermal expansion— general term. (See also **average coefficient of cubical expansion** and **average coefficient of linear expansion.**)

average grain diameter— See **grain size.**

axial ratio—the ratio of the length of one axis to that of another (for example, *c*/*a*) or the continued ratio of three axes (for example, *a*:*b*:*c*).

axis (crystal)—the edge of the unit cell of a space lattice. Any one axis of any one lattice is defined, in length and direction, with respect to the other axes of that lattice.

Babo's law—the vapor pressure over a liquid solvent is lowered approximately in proportion to the quantity of a nonvolatile solute dissolved in the liquid.

backing film—a film used as auxiliary support for the thin replica or specimen-supporting film.

back reflection—the diffraction of X-rays at a Bragg angle approaching 90°.

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.

band—in electron diffraction, a broad intensity maximum with sharp edges.

banded structure (banding)—alternate bands parallel with the direction of working resulting from the elongation of segregated areas.

barrel distortion— See **distortion.**

basal plane—that plane of a hexagonal or tetragonal crystal which is perpendicular to the axis of highest symmetry. Its Miller indices are (0001) or (001), respectively.

bellows length—the distance from the eyepiece to the photosensitive material or viewing screen in a photomicrographic apparatus.

Bertrand lens—an auxiliary removable lens in the body of a microscope, used to examine images in the back focal plane of the objective, for example, interference figures with polarized light.

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.

biased gun—an electron gun in which there is a bias voltage on the cathode cap. (See also **self-biased gun.**)

bifilar eyepiece—a Filar eyepiece with motion in two mutually perpendicular directions.

bi-modal grain size distribution—a condition where the distribution of individual grain areas or intercept lengths, converted to ASTM grain size numbers (based on the area percent or length percent per G class) exhibits two peaks.

binary alloy—any specific composition in a binary system.

binary system—the complete series of compositions produced by mixing a pair of components in all proportions.

binodal curve—in a two-dimensional phase diagram, a continuous line consisting of both of the pair of conjugate boundaries of a two-phase equilibrium and which join, without inflection, at a critical point. See **miscibility gap.**

birefringent—having more than one refractive index. Such materials exhibit alternately bright and dark reflections at 45° intervals during a 360° rotation with plane-polarized light. (See also **anisotropic**.)

bivariant equilibrium—a stable state among a number of phases equal to the number of components in a system and in which any two of the external variables (temperature, pressure, or concentrations) may be varied, at will, without necessarily causing a change in the number of phases; sometimes called divariant equilibrium.

blowholes—a hole produced in a casting by gas which was trapped during solidification.

body-centered—having an atom (or group of atoms) separated by a translation of ½, ½, ½ from a similar atom (or group of atoms). The number of atoms in a body-centered cell must be a multiple of two.

boiling pressure—at a specified temperature, the pressure at which a liquid and its vapor are in equilibrium.

boiling temperature—at a specified pressure, the temperature at which a liquid and its vapor are in equilibrium.

bonded abrasive disk—a rigid support surface with an abrasive, typically diamond, bonded to the surface by a ceramic, resin, or metal based material.

boundary grain—in the Jeffries' method for grain size measurement, a grain that is intersected by the boundary of the standard area and is, therefore, counted only as one-half grain. (See also **Jeffries' Method.**)

Bragg angle—the angle between the incident beam and the lattice planes considered.

Bragg equation:—

$$n\lambda = 2d\sin\theta \tag{2}$$

where:

n = order of reflection,
λ = wavelength of X-rays,
d = distance between lattice planes, and
θ = Bragg angle.

Bragg method—a method of X-ray diffraction in which a single crystal is mounted on a spectrometer with a crystal face parallel to the axis of the instrument.

Braun's law—the ratio of the solubility change with pressure, temperature being constant, $(\delta X/\delta P)T$, to the solubility change with temperature, pressure being constant, $(\delta X/\delta T)P$, is equal to the negative of the product of the absolute temperature, T, and the (fictitious) volume change (Δv) which accompanies the solution of 1 g·molecular weight of the solute in an infinitely large quantity of the saturated solution at T degrees, divided by the amount of heat, Q, developed in the process:

$$(\delta X/\delta P)T/(\delta X\,\delta T)P = -T\cdot\Delta v/Q \tag{3}$$

brightfield illumination— *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.

burning (burnt, burned)—a term applied to metal which has been permanently damaged by having been heated to a temperature close to or within the melting range. This results in a structure exhibiting incipient melting or intergranular oxidation.

calibration—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 micrometers or Kg/mm^2) to the instrument output (instrument units such as filar divisions or pixels).

caliper diameter (Feret's diameter)—the length of a line normal to two parallel lines, tangent to opposite edges of a phase or object.

carbide—a compound of carbon with one or more elements, which, in customary formulation, are considered as being more positive than carbon.

case—*in a ferrous alloy*, the outer portion that has been made harder than the inner portion (see **core**) as a result of altered composition, or structure, or both, from treatments such as carburizing, nitriding, and induction hardening.

cassette—a light-tight film or plate holder.

*cast replica***—**See **replica.**

cast structure—the structure, on a macroscopic or microscopic scale, of a casting.

cathode lens—a lens field terminated on one side by a surface at zero potential (cathode) normal to the optic axis. A cathode lens occurs in any system in which a cathode is imaged by its own electron emission, be it thermionic, photoelectric, secondary, or field emission.

cementite—a very hard and brittle compound of iron and carbon corresponding to the empirical formula Fe_3C. 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.

central pencil—a bundle of rays originating in the axis with an angular aperture equal to the effective aperture of the lens. These rays pass through the lens aperture and contribute to the formation of the image.

certified reference material—a reference material, the composition or properties of which are certified by a recognized standardizing agency or group. Typically such a material is accompanied by documentation (certificate).

characteristic curve—the curve showing the relationship between exposure and resulting density in a photographic image. It is usually plotted as the density against the log exposure. Called also the "H and D curve" and the "sensitometric curve."

characteristic radiation—X-radiation of a particular set of wavelengths, produced by and characteristic of a particular element used as a target whenever its excitation potential is exceeded.

charge neutralizer gun—an electron gun used to dissipate the charges which tend to build up on specimen surfaces, within an electron-diffraction camera, which would introduce undesired electrostatic fields.

chemical potential—(μ_i or $\bar{G}_i$) the partial molar free energy of component *i*, that is, the change in free energy of a solution upon adding one mole of component *i* to an infinite amount of solution of given composition,

$$\left(\delta G/\delta n_i\right)_{T,P,n_{1\ldots}} = \bar{G}_i = \mu_i \tag{4}$$

where:

G = Gibbs free energy, and
n_i = number of moles of the i^{th}component.

Chinese script eutectic—a configuration of eutectic constituents, found particularly in some cast alloys of aluminum containing iron and silicon and in magnesium alloys containing silicon, which resembles in appearance the characters in Chinese script.

chlorine or volatile halide extraction—See **extraction.**

chromatic aberration—a defect in a lens or lens system as a result of which the lens possesses different focal lengths for radiation of different wavelengths.

Class I quaternary equilibrium—in a four-component system, the stable univariant coexistence of five phases, one of which must disappear upon lowering the temperature or pressure; for example, the quaternary eutectic equilibrium, $L = \alpha + \beta + \gamma + \delta$.

Class I quinary equilibrium—in a five-component system, the stable univariant coexistence of six phases, one of which must disappear upon lowering the temperature or pressure; for example, the quinary eutectic equilibrium, $L = \alpha + \beta + \gamma + \sigma + \varepsilon$.

Class I ternary equilibrium—in a three-component system, the stable univariant coexistence of four phases, one of which must disappear upon lowering the temperature or pressure; for example, the ternary eutectic equilibrium, $L = \alpha + \beta + \delta$.

Class II quaternary equilibrium—in a four-component system, the stable univariant coexistence of five phases, two of which appear in each of the three associated bivariant equilibria at temperatures and pressures above, while the other three phases all occur in both of the associated bivariant equilibria below; for example, $L + \alpha = \beta + \gamma + \delta$.

Class II quinary equilibrium—in a five-component system, the stable univariant coexistence of six phases, two of which appear in each of the four associated bivariant equilibria at temperatures and pressures above, while the other four phases occur in both of the associated bivariant equilibria below; for example, $L + \alpha = \beta + \gamma + \delta + \varepsilon$.

Class II ternary equilibrium—in a three-component system, the stable univariant coexistence of four phases, two of which appear in both of the associated bivariant equilibria at higher temperature and pressure, while the other two phases occur in both bivariant equilibria below; for example, $L + \alpha = \beta + \gamma$.

Class III quaternary equilibrium—in a four-component system, the stable univariant coexistence of five phases, three of which appear in both of the associated bivariant equilibria at temperatures and pressures above, while the other two phases occur in all three of the associated bivariant equilibria below; for example, $L + \alpha + \beta = \gamma + \delta$.

Class III quinary equilibrium—in a five-component system, the stable univariant coexistence of six phases, three of which appear in all three of the associated bivariant equilibria at temperatures and pressures above, while the other three occur in all three of the associated bivariant equilibria below; for example, $L + \alpha + \beta = \gamma + \delta + \varepsilon$.

Class III ternary equilibrium—in a three-component system, the stable univariant coexistence of four phases, one of which must disappear at higher temperature or pressure; for example, the ternary peritectic equilibrium, $L + \alpha + \beta = \gamma$.

Class IV quaternary equilibrium—in a four-component system, the stable univariant coexistence of five phases, one of which must disappear at higher temperature or pressure; for example, the quaternary peritectic equilibrium, $L + \alpha + \beta + \gamma = \delta$.

Class IV quinary equilibrium—in a five-component system, the stable univariant coexistence of six phases, four of which appear in both associated bivariant equilibria at temperatures and pressures above, while the other two occur in all four

associated bivariant equilibria below; for example, $L + \alpha + \beta + \gamma = \delta + \varepsilon$.

Class V quinary equilibrium—in a five-component system, the stable univariant coexistence of six phases, one of which must disappear upon increasing the temperature or pressure; for example, the quinary peritectic equilibrium, $L + \alpha + \beta + \gamma + \delta = \varepsilon$.

Clausius-Clapeyron equation—the rate of change of the pressure of a heterogeneous equilibrium with change of temperature dP/dT is equal to the heat of transformation from the low to the high temperature state ΔHv divided by the product of the absolute temperature of the equilibrium and the volume change of the transformation $T\Delta V$:

$$dP/dT = \Delta Hv/T\Delta V \quad (5)$$

or,

$$d\ln P/dT \approx Hv/RT \quad (6)$$

where R is the gas constant and the equilibrium is not near a critical point.

clear cross test—an experimental method for determining which of two conceivable two-phase equilibria is real; at that composition at which the two conceivable two-phase fields cross, an alloy is brought to equilibrium and the phases identified; the same principle may be applied to higher-order equilibria in higher-order systems.

clear glass focusing screen—a glass screen polished on both sides and mounted for use in a camera, in lieu of photosensitive material, for the purpose of establishing a plane on which to focus an image prior to recording it.

cleavage planes—that family of planes of a crystal along which the crystal is easily split.

close packed—a geometric arrangement whereby a collection of equally sized spheres (atoms) may be packed together in a minimum total volume.

coefficient of thermal expansion—change in unit of length (or volume) accompanying a unit change of temperature, at a specified temperature.

coalescence—growth of grains at the expense of the remainder by absorption or the growth of a phase or particle at the expense of the remainder by absorption or by reprecipitation.

coarse grains—grains either larger than normal for the particular wrought metal or alloy, or grains of such a size that a surface roughening, popularly known as "orange peel" or "alligator skin," is produced.

coherent precipitate—a precipitated particle of a second phase, the lattice of which still maintains registry with the matrix lattice. Because the lattice spacings are usually different, strains usually exist at the interface.

coherent scattering—a kind of X-ray electron scattering in which the phase of the scattered beam has a definite (not random) relation to the phase of the incident beam. Also called unmodified scattering.

cold-cathode gun—an electron gun in which electrons produced in a gas discharge are accelerated through a small aperture in the anode.

cold junction—See **reference junction.**

cold junction correction— See **reference junction correction.**

cold worked structure—a microstructure resulting from plastic deformation of a metal or alloy below its recrystallization temperature.

collimation—the operation of controlling a beam of radiation so that its rays are as nearly parallel as possible.

collodion replica— See **replica.**

color film—a photographic film consisting of several emulsion layers, where the individual layers selectively record various wavelengths of light.

color temperature—the temperature of a blackbody in degrees Kelvin (K). In photography, the apparent temperature in K of a luminous source which may be measured by its emission ratio of blue to red light.

column, electron microscope—the assembly of gun, lenses, and specimen, viewing and plate chambers.

columnar structure—a macro- or microstructure characterized by elongated grains whose long axes are parallel, for example, to solidification direction, electroplated direction, etc.

comparison standard—a standard micrograph or a series of micrographs, usually taken at 75 or 100 diameters, or a suitable equivalent built into the eyepiece and used to determine grain size by direct comparison with the image.

compensating eyepiece—one designed for use with objectives such as apochromats, the lateral chromatic aberration of which is undercorrected.

compensating lead wires—wires leading from a thermocouple to the voltage-measuring instrument. These wires must be of such compositions that they will generate an *emf* equivalent to the *emf* generated by the reference junction of the couple.

complex silicate inclusions—a general term describing silicate inclusions containing visible constituents besides the silicate matrix. An example would be corundum or spinel crystals occurring in a silicate matrix in steel.

component—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.

composition—the quantity of each of the components of a mixture; usually expressed in terms of the weight percentage, or the atomic percentage of each of the components in the mixture.

Compton scattering—X-ray scattering by atoms in which the scattered beam has, relative to the incident beam, a longer

wavelength and a random phase relationship. Also called incoherent or modified scattering.

condensed system—a pure substance, or mixture, at a pressure and temperature such that the vapor phase does not exist.

condenser—a term applied to lenses or mirrors designed to collect, control, and concentrate radiation in an illumination system.

condenser aperture— See **aperture.**

condenser lens—a device used to focus radiation in or near the plane of the object.

congruent transformation—an isothermal, or isobaric, phase change in which both of the phases concerned have the same composition throughout the process; the order of a system becomes unary at a composition of congruency.

conjugate phases—those states of matter of unique composition which coexist at equilibrium at a single point in temperature and pressure; for example, the two coexisting phases of a two-phase equilibrium.

conjugate planes—two planes of an optical system such that one is the image of the other.

constituent—a phase, or combination of phases, which occurs in a characteristic configuration in an alloy micro-structure.

constitutional diagram—graphical representation of the compositions, temperatures, pressures or combinations thereof at which the heterogeneous equilibria of an alloy system occur; also called "phase diagram," or "equilibrium diagram."

continuous phase—the phase forming the matrix or background in which other phases may be dispersed as isolated units.

continuous spectrum (X-rays)—the polychromatic radiation given off by the target of an X-ray tube, containing all wavelengths above a certain minimum value called the short wave length limit.

contrast enhancement (electron optics)— an improvement in electron image contrast by the use of an objective aperture diaphragm, shadow casting, or other means.

contrast perception—the ability to differentiate various components of the object structure by different intensity levels in the image.

contrast, photographic—the word contrast has been used in many different senses in connection with various photographic characteristics; there are different types of photographic contrast and different methods of measuring it. It is frequently used to designate the magnitude of the density difference resulting from a given exposure difference. (For another use, see **gamma**.)

conversion, hardness—the exchange of a hardness number determined by one method for an equivalent hardness number of a different scale.

cooling curve—graphical representation of the course of temperature fall of a chemical mixture as a function of time commonly exhibiting more or less abrupt changes of rate at, or near, those temperatures at which phase changes begin; used in finding the temperatures at which phase changes occur. Occasionally, some property or function other than time may be used; for example, thermal expansion.

cooling rate—the average slope of the time-temperature curve taken over a specified time and temperature interval.

core—(*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.

coring—a variable composition between the center and outside of a unit of structure, (such as a dendrite, grain, carbide particle) resulting from non-equilibrium growth which occurs over a range of temperatures or compositions.

corona shield—a smooth, rounded metal covering placed around exposed high-voltage components to prevent electrical discharge.

counter—a device for the measurement of radiation intensity by means of an electrical triggering principle (Geiger-Müller).

coupler, color—a substance capable of reacting with the oxidation product of a color-forming developer to produce a colored dye image.

critical curve—in a binary, or higher order, phase diagram, a line along which the phases of a heterogeneous equilibrium become identical.

critical point—in a phase diagram, that specific value of composition, temperature, pressure or combinations thereof at which the phases of a heterogeneous equilibrium become identical. (See also **transformation temperature.**)

critical pressure—that pressure above which the liquid and vapor states are no longer distinguishable.

critical surface—in a ternary, or higher order, phase diagram, the area upon which the phases in equilibrium become identical.

critical temperature—that temperature above which the vapor phase cannot be condensed to liquid by an increase in pressure.

cross direction—one of three mutually perpendicular directions used to define a worked material, specifically that direction in the plane of working which is at right angles to the direction of maximum elongation.

crystal—a solid composed of atoms, ions, or molecules arranged in a pattern which is periodic in three dimensions.

crystal analysis—a method for determining crystal structure, for example, the size and shape of the unit cell and the location of all atoms within the unit cell.

crystallite—a crystalline grain not bounded by habit planes.

crystal system—one of seven groups into which all crystals may be divided; triclinic, monoclinic, orthorhombic, hexagonal, rhombohedral, tetragonal, and cubic.

cube texture—a texture found in wrought metals in the cubic system, in which nearly all the crystal grains have a plane of the type (100) parallel or nearly parallel to the plane of working and a direction of the type [001] parallel or nearly parallel to the direction of elongation.

cubic—having three mutually perpendicular axes of equal length.

cupping—the condition sometimes occurring in heavily cold worked rods and wires, in which the outside fibers are still intact and the central zone has failed in a series of cup-and-cone fractures.

Curie point—that temperature above which a substance becomes paramagnetic.

curvature of field—a property of a lens that causes the image of a plane to be focused into a curved surface instead of a plane.

darkfield illumination—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.

dashpot—a hydraulic cylinder device with a controlled leak designed to eliminate impact loading of mechanisms. Hardness testers may employ a dashpot to bring an indenter into contact with a specimen without impact or other disturbance.

dead-weight loading—a method of loading in which a weight is supported solely by the specimen and has no other mechanical connection to the testing machine. In hardness testing, the weight is supported by the indenter.

Debye ring—a continuous circle, concentric about the undeviated beam, produced by monochromatic X-ray diffraction from a randomly oriented crystalline powder. An analogous effect is obtained with electron diffraction.

Debye-Scherrer method—a method of X-ray diffraction employing monochromatic radiation and a polycrystalline specimen mounted on the axis of a cylindrical strip of film. (See **powder method.**)

decarburization—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.

deep etching—macroetching; etching preliminary to macroexamination, intended to develop gross features such as segregation, grain flow, cracks or porosity.

define (X-rays)—limit a beam of X-rays by passage through apertures in order to obtain a parallel, divergent, or convergent beam.

definition—the clarity or sharpness of a microscopical image.

deformation bands—bands produced within individual grains during cold working which differ variably in orientation from the matrix.

deformation lines—thin bands or lines produced in grains of some metals, particularly those of face-centered cubic structure, by cold working; they are not removed by repolishing and re-etching.

degree of freedom—in heterogeneous equilibrium, an external variable that may be adjusted independently without causing a change of state; the external variables usually considered are: temperature, pressure, and concentration parameters numbering one less than the order of the system.

delta ferrite—designation commonly assigned to delta iron containing alloying elements in solid solution. Small amounts of carbon and large amounts of other alloying elements markedly affect the high-and-low-temperature limit of equilibrium.

delta iron (δ Fe)—solid phase of pure iron which is stable at temperatures between 1400 and 1539°C and possesses the body-centered cubic lattice. Strictly, there is no difference between delta and alpha iron.

denatured alcohol—ethyl alcohol containing an addition of a poisonous substance, making it unfit for human consumption.

dendrites—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.

densitometer—an instrument which measures the relationship between incident light and transmitted or reflected light and, using a logarithmic scale, gives a numerical measurement that corresponds to a material's opacity or a film's photographic density.

density (film)—transmission density is the common logarithm of the ratio of the radiant flux incident on the sample to the radiant flux transmitted by the sample, assuming no reflection.

deoxidation products—a term specifically applied to those non-metallic inclusions formed as a result of the addition of deoxidizing agents to molten metal.

depletion—selective removal of one component of an alloy, usually from the surface or preferentially from grain boundary regions.

depth of field—the depth or thickness of the object space that is simultaneously in acceptable focus.

depth of focus—the depth or thickness of the image space that is simultaneously in acceptable focus.

derived differential curve—the curve derived from the data obtained by the use of the differential method of thermal analysis. The changes in the temperature difference $\Delta(\theta - \theta')$, between a specimen and a neutral body, for a constant interval of temperature $\Delta\theta$ are plotted against the temperature. An arithmetic treatment of the differential data resulting in a plot of $\Delta(\theta - \theta')/\Delta\theta$ *versus* θ. (See **differential curve.**)

descending fork point—in a ternary phase diagram, the configuration at the convergence of the three divariant curves upon each of the three high-temperature phases associated in Class III univariant equilibrium; for example, the division of a descending liquidus surface valley into two descending liquidus-surface valleys.

detected feature—*in image analysis*, an object or constituent of interest that is isolated for measurement by adjustment of the threshold setting to its particular range of gray level.

deviation (X-ray)—the angle between the diffracted beam and the transmitted incident beam. It is equal to twice the Bragg angle θ.

devitrification—crystallization of an amorphous substance.

dezincification—a type of corrosion found with some copper-zinc alloys which occurs by solution of a small region and immediate redeposition of the copper in a spongy porous form, thus giving the impression of selective removal of zinc from the alloy.

diagonal—in hardness testing, a line joining two opposite corners of a diamond pyramid indentation.

differential curve: (*1*) *in thermal analysis*——a curve resulting from the differential method of thermal analysis when the difference in temperature $(\theta - \theta')$ between a specimen and a neutral body is plotted against the temperature of the latter.

(*2*) *in dilatometry*—a curve produced by plotting against the temperature the difference in changes of length or volume between a body of known expansivity and a body (specimen) of unknown expansivity.

differential interference contrast illumination—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.

differential thermocouple—two thermocouples placed in series opposition (bucking).

diffraction:—(*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.

diffraction grating—an artificially produced periodic array of scattering centers capable of producing a pattern of diffracted energy, such as accurately ruled lines on a plane surface.

diffraction pattern (X-rays)—the spatial arrangement and relative intensities of diffracted beams.

diffraction ring—the diffraction pattern produced by a given set of planes from randomly oriented crystalline material. (See also **Debye ring.**)

diffusion-transfer process—a rapid photographic process in which a negative image is produced at one location, with unused imaging materials then diffusing across a thin fluid layer to produce a positive image on a receptor sheet.

diffusion zone—the zone of viable composition at the junction between two different materials, such as in welds or between the surface layer and the core of clad materials or bearings, in which interdiffusion between the various components has taken place.

dilatometer—the instrument used in dilatometry for measuring lengths or volume changes.

dilatometry—the measurement of length or volume changes of a substance undergoing a change in temperature, pressure, or state. See Practice E80.

direct print—a photographic print of an original negative.

discontinuous stringer—three or more Type B or C inclusions aligned in a plane parallel to the hot working axis and offset by no more than 15 µm with a separation of less than 40 µm (0.0016 in.) between the two nearest neighbor inclusions (see Practices E45 and E1122).

disordered structure—the crystal structure of a solid solution in which the atoms of different elements are randomly distributed with respect to the available lattice sites.

dispersoid—in metallography, finely divided particles of relatively insoluble constituents which can be seen in the microstructure of certain alloys.

dissociation—as applied to heterogeneous equilibria, the transformation of one phase into two, or more, new phases, all of different composition.

dissociation pressure—at a designated temperature, the pressure at which a phase will transform into two, or more new phases, of different composition.

distortion—an aberration of lens systems where axial and marginal magnifications are unequal.

(*1*)*barrel distortion*—the distortion in the image which occurs when the magnification of the image in the center of the field is greater than in the edge of the field. This is also

called negative distortion.

(*2*) *pincushion distortion*—the distortion in the image which results when the magnification in the center of the field is less than it is at the edge of the field. This is also called positive distortion.

divorced eutectic—a structure in which the components of an eutectic appear to be entirely separate.

double boiling system—a series of mixtures characterized by the vaporization of a liquid phase in one temperature (or pressure) range and the vaporization of another liquid phase within another temperature (or pressure) range; for example, a salt and water mixture which boils with the expulsion of water at moderately elevated temperature and then at higher temperature the molten salt itself boils to produce salt vapor.

double melting system—a series of mixtures which, with rising temperature, first develops a liquid phase that is totally converted to vapor before a second liquid phase appears; for example, a salt and water mixture which, upon heating, first melts to an aqueous solution of the salt, the water then boils away and the salt residue itself melts.

doublet (in characteristic X-ray spectra)— a separation of characteristic radiation into subspecies of slightly different wavelength.

drift—in electron optics, motion of the electron beam or image due to current, voltage or specimen instabilities or charging of a projection such as dirt in or near the electron beam.

dry objective—any microscopical objective designed for use without immersion liquids.

duplex microstructure—a two-phase structure.

duplex grain size—the simultaneous presence of two grain sizes, in substantial amounts, with one grain size appreciably larger than the other. (Synonymous with **mixed grain size.**)

dynamical theory—the explanation of diffraction phenomena in terms of dynamical interaction between the incident beam, all scattered waves and the crystal lattice, where the latter is treated as a triply periodic field of potential.

dystetic equilibrium—synonymous with **eutectoid equilibrium.**

Eberbach—See **micro penetration tester.**

edge angle—the included angle between two opposite edges of a hardness indenter.

elastic electron scatter—the scatter of electrons by an object without loss of energy, usually an interaction between electrons and atoms.

elastic recovery—in hardness testing, the shortening of the original dimensions of the indentation upon release of the applied load.

electrolytic extraction— See **extraction.**

electrolytic polishing—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.

electromagnetic focusing device—See **focusing device.**

electromagnetic lens—an electromagnet designed to produce a suitably shaped magnetic field for the focusing and deflection of electrons or other charged particles in electron-optical instrumentation.

electron—a subatomic particle having a negative charge of 4.8025×10^{-10} esu, and a charge-to-mass ratio or specific charge of $5.2737 \pm 0.0015 \times 10^{17}$ esu/g.

electron beam—a stream of electrons in an electron optical system.

electron diffraction—the phenomenon, or the technique of producing diffraction patterns through the incidence of electrons upon matter.

electron gun—a device for producing and accelerating a beam of electrons.

electron image—a representation of an object formed by a beam of electrons focused by an electron optical system (See **image.**)

electron lens—a device for focusing an electron beam to produce an image of an object.

electron micrograph—a reproduction of an image formed by the action of an electron beam on a photographic emulsion.

electron microscopy—the study of materials by means of the electron microscope.

electron microscopy impression—See **impression.**

electron optical axis—the path of an electron through an electron optical system along which it suffers no deflection due to lens fields. This axis does not necessarily coincide with the mechanical axis of the system.

electron optical system—a combination of parts capable of producing and controlling a beam of electrons to produce an image of an object.

electron optics—the science that deals with the propagation of electrons, as light optics deals with that of light and its phenomena.

electron probe—a narrow beam of electrons used to scan or illuminate an object or screen.

electron trajectory—the path of an electron.

electron velocity—the rate of motion of an electron.

electron wavelength—the wavelength necessary to account for the deviation of electron rays in crystals by wave diffraction theory. It is numerically equal to the quotient of Planck's constant divided by the electron momentum. This is approximately $\lambda = (12.3/V)$ *A*., where V = the accelerating potential in volts.

electrostatic focusing device—See **focusing device.**

electrostatic immersion lens—See **immersion objective**

electrostatic lens—a lens producing a potential field capable of deflecting electron rays to form an image of an object.

elongated grain—a grain with one principal axis significantly longer than either of the other two.

emission microscope—a type of electron microscope in which the specimen is the cathode source of the electrons. Sometimes used synonymously with shadow microscope.

enantiotropic transformation—a reversible metastable phase change; for example, the freezing of sulfur directly to the rhombic phase, or the direct melting of the latter, without passing through the stable intermediate monoclinic phase.

end-centered—having an atom (or group of atoms) separated by a translation of the type ½, ½, 0 from a similar atom (or group of atoms). The number of atoms in an end-centered cell must be a multiple of two.

epsilon (ε)—designation generally assigned to intermetallic, metal-metalloid, and metal-nonmetallic compounds found in ferrous alloy systems (for example, Fe_3Mo_2, $FeSi$, Fe_3P).

epsilon carbide—carbide with hexagonal close-packed lattice which precipitates during the first stage of tempering of primary martensite. Its composition corresponds to the empirical formula $Fe_{2\cdot4}C$.

epsilon structure—structurally analogous close-packed phases (similar to epsilon brass), or electron compounds, that have ratios of 7 valence electrons to 4 atoms.

equiaxed grain—a polygonal crystallite, in an aggregate, whose dimensions are approximately the same in all directions.

equilibrium—a state of dynamic balance between the opposing actions, reactions, or velocities of a reversible process.

equilibrium diagram— See **constitutional diagram.**

etch figures—markings formed on a crystal surface by etching or chemical solution and usually related geometrically to the crystal structure.

etching—controlled preferential attack on a metal surface for the purpose of revealing structural details.

eutectic alloy—the alloy which has the composition of the eutectic point.

eutectic arrest—in a cooling curve (or heating curve) an approximately isothermal segment, corresponding to the time interval during which the heat of transformation from the liquid phase to two or more conjugate solid phases is being evolved, (or conversely).

eutectic carbides—in hypereutectic tool steels, the skeleton-like structure of the eutectic carbide.

eutectic colony, grain—a two-phase region which solidified progressively from a simple center and, therefore, has some uniformity of structural relationship.

eutectic equilibrium—a reversible univariant transformation in which a liquid, that is stable only at superior temperature, decomposes into two or more conjugate solid phases; for example, $L = \alpha + \beta$, $L = \alpha + \beta + \gamma$, etc.

eutectic point—the composition of a liquid phase that is in univariant equilibrium with two or more solid phases; the lowest melting alloy of a composition series.

eutectic structure—the structure resulting when an alloy has passed through a eutectic equilibrium upon freezing.

eutectoid equilibrium—a reversible univariant transformation in which one solid phase, that is stable only at superior temperature, decomposes into two or more conjugate solid phases; for example, $\alpha = \beta + \gamma$, $\alpha = \beta + \gamma + \delta$, etc.

eutectoid point—the composition of a solid phase which, upon cooling, undergoes univariant transformation into two, or more, other solid phases.

eutectoid reaction— See **eutectoid equilibrium.**

eutectoid structure—the microstructure resulting when an alloy has passed through an eutectoid equilibrium upon cooling.

evaporation—the vaporization of a material by heating it, usually in a vacuum. In electron microscopy this process is used for shadowing or to produce thin support films by condensation of the vapors of metals or salts.

Ewald sphere—a geometric construction, of radius equal to the reciprocal of the wavelength of the incident radiation, with its surface at the origin of the reciprocal lattice. Any crystal plane will reflect if the corresponding reciprocal lattice point lies on the surface of this sphere.

excitation potential—the applied potential on an X-ray tube required to produce characteristic radiation from the target.

exogenous inclusion—a nonmetallic constituent produced by entrapment of foreign material in the melt. (See **inclusions.**)

expansion curve, thermal—the curve produced by plotting a dimension or the volume of a substance versus the temperature.

exposure:—(*1*) The act of submitting material to radiation to which it is sensitive.

(*2*) the quantitative measure of exposure as a function of intensity and time of the radiation (often the product of $I \times t$) falling on a sensitive material.

(*3*) *X-ray*—the product of X-ray intensity and time.

exposure index—the rating of a film for use in connection with exposure tables, exposure computers, and exposure meters. (See also **sensitivity.**)

exposure scale—in a photographic process, the range of exposure over which substantially correct reproduction is obtained. This is measured by the ratio of the exposure corresponding to the minimum useful gradient at the high exposure end of the scale to that corresponding to the minimum useful gradient at the low exposure end.

extension lead wires—wires leading from a thermocouple to the voltage-measuring instrument. These wires should have the same temperature-emf relationship as the thermocouple wires.

extinction—a decrease in the intensity of the diffracted beam caused by perfection or near perfection of crystal structure. (See also **primary extinction and secondary extinction.**)

extinction coefficient—the ratio of the diffracted beam intensity when extinction is present to the diffracted beam intensity when extinction is absent. It is applicable to either **primary** or **secondary extinction.**

extraction—a general term concerning chemical methods of isolating phases from the metal matrix.

(*1*)*acid extraction*—removal of phases by dissolution of the matrix metal in an acid.

(*2*)*chlorine extraction*—removal by formation of a volatile chloride.

(*3*)*electrolytic extraction*—removal by using an electrolytic cell containing an electrolyte which preferentially dissolves the metal matrix.

eye clearance—the distance from the back lens of an eyepiece to the proper location of the viewer's eye, typically about 8 mm (about 20 mm for high eyepoint eyepieces which permit the use of eyeglasses).

eye lens—the lens in an eyepiece nearest to the eye.

eyepiece—the lens system used in an optical instrument for magnification of the image formed by the objective.

eyepiece micrometer— See **ocular micrometer.**

face angle—the included dihedral angle between two opposite faces of an indenter.

face-centered—having atoms (or groups of atoms) separated by translations of ½, ½, 0; ½, 0, ½ ; and 0, ½, ½ from a similar atom (or group of atoms). The number of atoms in a face-centered cell must be a multiple of four.

face (crystal)—an idiomorphic plane surface on a crystal.

family (of crystal planes)—the planes in any one crystal that have common Miller indices, regardless of sign.

feature-specific measurement, *n*—an individual measurement of each detected feature in the field of view.

Feret's diameter—See **caliper diameter.**

ferrite—designation commonly assigned to alpha iron containing alloying elements in solid solution. Increasing carbon content markedly decreases the high-temperature limit of equilibrium.

ferrite grain size—the grain size of the ferrite in predominantly ferritic steels. See Test Methods E112.

ferritizing anneal—the process of producing a predominantly ferritic matrix in a ferrous alloy through an appropriate heat treatment.

fiber (fibre)—a structural feature of wrought metal revealed by directional properties, manifested by the appearance of an etched longitudinal section, by the appearance of a fracture, or by an X-ray pattern of crystal orientations.

fiber-axis—the preferred direction of fiber texture.

fiber texture—a texture characterized by having only one preferred crystallographic direction.

field—the portion of the object in view.

field lens—the lens nearest the field diaphragm in an eyepiece.

field measurement, in image analysis—the aggregate measurement of the detected features in a field of view.

filament—an electrically heated wire used as a source of a radiation, such as electrons, or as a source of heat, such as in the vaporization of a metal.

filar micrometer or filar eyepiece—an eyepiece equipped with a fiducial line in its focal plane, which is movable by means of a calibrated micrometer screw, in order to make accurate measurements of length.

film cassette—See **cassette.**

filter—a device which modifies the light coming from the light source either chromatically or with regard to intensity.

(*1*) *color*—a device which transmits principally a predetermined range of wavelengths.

(*2*) *contrast*—a color filter, usually with strong absorption, whose function is to utilize the spectral absorption bands of the subject to control the contrast of the image by exaggerating or diminishing the brightness difference between areas of different color. Maximum contrast is obtained when the transmission of the filter is entirely within the absorption band of an area but not of its surroundings.

(*3*) *interference*—a combination of several thin optical films to form a layered coating for transmitting or reflecting a narrow band of wavelengths by virtue of interference effects.

(*4*) *neutral*—(*a*) a color filter that reduces the intensity of the transmitted illumination without affecting its hue.

(*b*) a color filter having identical transmission at all wavelengths throughout the spectrum. Such an ideal filter does not exist in practice.

(*5*) *orthochromatic*—a color filter whose function is to modify the illumination quality reaching the film so that the brightness of colored objects will be relatively the same in the resultant black-and-white positive.

(*6*) *photometric*—a color filter whose function is to convert the quality of illumination from that of one source to that of another. Most frequently the term is used for a filter altering the illumination quality from that of one color temperature to that of another.

(*7*) *X-Ray*—a material that preferentially absorbs certain wavelengths.

fire crack—cracking, frequently intergranular in nature, that occurs in some metallic materials when too rapidly heated or when stressed and heated rapidly. Not to be confused with "quench crack."

fire scale—copper oxide subscale formed just under the surface of silver-copper alloys when they are annealed in air.

flakes—in wrought ferrous products, flakes appear as short discontinuous internal cracks attributed to stresses produced by localized transformation and hydrogen solubility effects

during cooling after hot working. They appear in a fracture surface as bright silvery areas with a coarse texture. In deep acid-etched transverse section they appear as discontinuities which are usually located in the midway to center location of the section. Known also as shatter cracks and hairline cracks.

flatness of field—a qualitative term describing how well the image of a planar specimen is reproduced as a plane in the image field. (See **curvature of field**.)

flexure plate pivot—a type of pivot or hinge in which the motion occurs through the bending of a thin elastic plate.

flicker method, *in image analysis* **—**the procedure of alternating between the live video image and the detected image while altering the gray-level threshold range to establish the optimum discrimination and detection.

flow lines—a fiber pattern, frequently observed in wrought metal, which indicates the manner in which the metal flowed during deformation.

fluorescent screen—a sheet of material which emits visible light when exposed to invisible radiation.

fluorescent X-rays (fluorescent analysis)— characteristic X-rays excited by radiation of wavelength shorter than the corresponding absorption edge.

focal length—the distance from the second principal point to the point on the axis where parallel rays entering the lens will converge or focus.

focal spot—that area on the target of an X-ray tube which is bombarded by electrons.

focus—a point at which rays originating from a point in the object converge or from which they diverge or appear to diverge under the influence of a lens or diffracting system.

focusing (X-rays)—the operation of producing a convergent beam in which all rays meet in a point or line.

focusing device (electrons)—a device which effectively increases the angular aperture of the electron beam illuminating the object, rendering the focusing more critical.

focusing magnifier: (*1*)**—**a low-power microscope, telescope or simple lens used to observe the electron image formed on a fluorescent screen.

(*2*) a magnifying lens mounted so that its focal plane is coincident with its base, used to obtain a sharp focus in the plane of the sensitive material in a camera.

foil—a thin sheet of a material, usually a metal, not exceeding 0.005 in. in thickness.

folds—defects in metal, usually on or near the surface, caused by continued fabrication of overlapping surfaces.

forged structure—the macrostructure through a suitable section of a forging which reveals direction of working.

form—a set of equivalent planes in a crystal. In general, they will have the same spacing but different Miller indices. For example, in the cubic system, the planes (101), (110), (011), etc. are planes of the form (110). In the tetragonal system, however, the planes (101) and (110) belong to different forms. Equivalent directions are also spoken of as directions of a form.

Formvar—a plastic material used for the preparation of replicas, or specimen supporting membranes. Trade name for poly(vinyl formal) 15/95.

*Formvar replica***—**See **replica**.

fracture grain size—grain size determined by comparing a fracture of a specimen with a set of standard fractures. For steel, a fully martensitic specimen is generally used and the depth of hardening as well as the prior austenitic grain size is determined.

fracture test: (*1*) **—***general*the production of a fracture in a metal sample to determine such things as discontinuities, grain size, and composition.

(*2*) *steel*—a test which utilizes a hardened steel disk section prepared from billet or bar stock which is fractured parallel to the grain flow so that, among other things, discontinuities due to inclusion segregates can be detected visually.

free-energy diagram—a graphical representation of the variation with concentration of the Gibbs Free Energy, at constant pressure and temperature.

free-energy surface—in a ternary, or higher order, free energy diagram, the locus of points representing the Gibbs Free Energy as a function of concentration, with pressure and temperature constant.

*freezing point***—**See **melting point**.

frequency (X-ray)—the number of alternations per second of the electric vector of the X-ray beam. It is equal to the velocity divided by the wavelength.

Fresnel fringes—a class of diffraction fringes formed when the source of illumination and the viewing screen are at a finite distance from a diffracting edge. In the electron microscope these fringes are best seen when the object is slightly out of focus.

gamma (photography)—the tangent of the angle which the straight-line part of the characteristic curve makes with the log exposure axis and in a photographic film or plate is a measure of the extent of development.

gamma iron (γ Fe)—solid nonmagnetic phase of pure iron which is stable at temperatures between 910 and 1400°C and possesses the face-centered cubic lattice.

gas holes—blow holes, channels, or porosity produced by gas evolution, usually during solidification.

gate—a valve placed in a vacuum system to facilitate the isolation of a selected section of the system.

*Geiger-Müller counter***—**See **counter**.

*gelatin replica***—**See **replica**.

general precipitate—a precipitate which is dispersed throughout the matrix.

Gibbs free energy—the maximum useful work that can be obtained from a chemical system without net change in temperature or pressure; $\Delta F = \Delta H - T\Delta S$.

Gibbs triangle—an equilateral triangle, used for plotting composition in a ternary system.

glancing angle—the angle (usually small) between an incident X-ray beam and the surface of the specimen.

gnomonic projection—a projection in which the orientation of a crystal plane at the center of the unit sphere is represented by the point where the plane normal intersects the plane of projection which is tangent to the unit sphere at the zenith.

goniometer—an instrument devised for measuring the angle through which a specimen is rotated.

gradient furnace—a furnace within which a known temperature gradient is maintained between the two ends. Sometimes known as a Rosenhain Furnace.

grain—an individual crystallite in metals.

grain boundary—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.

grain growth—an increase in the grain size of a metal usually as a result of heating at an elevated temperature.

grain size—the dimensions of the grains or crystals in a polycrystalline metal exclusive of twinned regions and subgrains when present. Grain size is usually estimated or measured on the cross section of an aggregate of grains. Common units are: (*1*) average diameter, (*2*) average area, (*3*) number of grains per linear unit, (*4*) number of grains per unit area, and (*5*) number of grains per unit volume. See Test Methods E112.

(*1*) *ASTM grain size number*—a grain size designation bearing a relationship to average intercept distance at 100 diameters magnification according to the equation: G = ASTM grain size number = $10.0 - 2 \log_2 \bar{L}$, where $\bar{L}$ is the average intercept distance in millimetres at 100 magnification.

(*2*) *average grain diameter*—the mean diameter of an equiaxed grain section whose size is representative of all the grain sections in the aggregate being measured.

grain size comparison eyepiece—an eyepiece provided with calibrated patterns representing a series of standard sizes of grains. The eyepiece must be used at a total magnification for which the patterns have been calibrated.

graphite, flake—an irregularly shaped body, usually appearing as long curved plates of graphitic carbon such as found in gray cast irons.

graticule—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, see **reticle**).

gray level, in image analysis—a specific neutral color value existing within the range from black to white.

grinding—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 μm) but may be finer.

ground-glass focusing screen—a glass screen, one side of which is ground or made diffusing and mounted for use in a camera, in place of photosensitive material, for the purpose of intercepting, viewing, and focusing a real image formed on it.

guard frame—in video-based automatic image analysis, an internal border, smaller than the monitor image frame, used to restrict the measurement area and thus eliminate errors in sizing features that interesect the measurement area border when used in conjunction with specific feature selection rules (also called the active frame).

guard region—in video based automatic image analysis, that portion of the imaged area between the guard (active) frame and the image frame which is employed in a variety of ways to eliminate sizing errors of features that intersect the guard frame.

Guinier-Preston streak—an elongated spot on the Laue pattern from a single crystal which first appears during age hardening.

Guinier-Preston zones—those regions of a crystal which give rise to Guinier-Preston streaks.

H and D curve—See **characteristic curve**.

habit plane—crystallographic plane in a parent phase along which a new phase (or phases) is (are) generated.

hard (X-rays)—of short wavelength.

hardness impression—See **impression**.

heating curve—graphical representation of the course of temperature rise of a sample or body as a function of time.

heterogeneous—non-uniform in microstructure or composition.

heterogeneous equilibrium—in a chemical system, a state of dynamic balance amongst two or more homogeneous phases which are capable of stable coexistence in mutual or sequential contact.

hexagonal (concerning lattices for crystals)—Having two equal coplanar axes, a_1 and a_2, at 120 deg to each other and a third axis, c, at right angles to the other two; c may or may not be equal to a_1 and a_2.

hexagonal close packed:—(*1*) a structure containing two atoms per unit cell located at (0, 0, 0) and (⅓, ⅔, ½) (or ⅔, ⅓, ½).

(*2*) one of the two ways in which spherical objects can be most closely packed together, such that the close-packed planes are alternately staggered in the order A-B-A-B-A-B.

Heyn method—an intercept method for determining grain size. See Test Methods E112.

Homal eyepiece—See **amplifier**.

homogeneous (radiation) (monochromatic)—of the same wavelength.

hot cathode—a heated element of a vacuum enclosed electrical system emitting electrons thermionically. It is maintained at a potential negative with respect to a second element to accelerate the emitted electrons.

hot junction—See **measuring junction**.

hot worked structure—the structure of a material worked at a temperature higher than the recrystallization temperature.

Huygens eyepiece—an achromatic eyepiece invented by Huygens and consisting of a plano-convex eyelens and a plano-convex collective, between which is a field diaphragm.

hypereutectic alloy—any composition between the eutectic point and the composition of that solid phase, of the pair into which the eutectic liquid decomposes, which is considered the less important; thus, the identification of the hypereutectic range, as distinguished from the hypoeutectic range, is a matter either of personal preference, or a common usage for each alloy system.

hypereutectoid alloy—any composition between the eutectoid point and the composition of that solid phase, of the pair into which the eutectoid solid phase decomposes, which is considered the less important; for the meaning of "important," see **hypereutectic alloy**.

hypereutectoid structure—the microstructure of a hypereutectoid alloy. For example, microstructural aggregate found in iron-carbon alloys which consist of primary crystals of cementite together with nodules of pearlite.

hypoeutectic alloy—any composition between the eutectic point and the composition of that solid phase, of the pair into which the eutectic liquid decomposes, which is considered the more important; for the meaning of "important," see **hypereutectic alloy**.

hypoeutectoid alloy—any composition between the eutectoid point and the composition of that solid phase, of the pair into which the eutectoid solid phase decomposes, which is considered the more important; for the meaning of "important," see **hypereutectic alloy**.

hypoeutectoid structure—the microstructure of a hypoeutectoid alloy. For example, the microstructural aggregate found in iron-carbon alloys which consist of primary crystals of ferrite together with nodules of pearlite.

identity period—the distance between equivalent points in adjacent unit cells, usually measured in a direction parallel to a crystal axis.

idiomorphic crystal—single crystals that have grown without restraint so that the habit planes are clearly developed.

illumination—See **brightfield, conical, darkfield, polarized light**.

image—a representation of an object produced by means of radiation, usually with a lens or mirror system.

image processing, in image analysis—the computer modification of a digitized image on a pixel-by-pixel basis to emphasize or de-emphasize certain aspects of the image.

image rotation—in electron optics, the angular shift of the electron image of an object about the optic axis induced by the tangential component of force exerted on the electrons perpendicular to the direction of motion in the field of a magnetic lens.

immersion lens—See **immersion objective**.

immersion objective—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.

immersion objective (electron optics)—a lens system in which the object space is at a potential (or in a medium of index of refraction) different from that of the image space.

impact loading—in hardness testing, a phenomenon in which a momentary overload is inadvertently applied to the indenter by the inertia of parts of the tester subjected to large accelerations.

impression: (*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.

(*2*) *hardness*—the imprint or dent made in the specimen by the indenter of a hardness-measuring device.

impression replica—See **replica**.

inclusion count—determination of the number, kind, size, and distribution of non-metallic inclusions. See Practice E45.

inclusions—foreign material held mechanically, usually referring to non-metallic particles, such as oxides, sulfides, silicates, etc.

incoherent electron scatter—the deflection of electrons by either electrons or atoms which results in a loss of kinetic energy by the incident electron.

incongruent transformation—a nonisothermal, or nonisobaric, phase change in which one, or both, of the phases involved undergo composition change during the process.

indent—See **impression**.

indentation—See **impression**.

indenter—in hardness testing, a tool, usually of diamond and having a definite geometrical shape, which is forced into the surface of the specimen.

indenter constant—in hardness testing, a numerical constant relating the area of the indentation to the square of the measured diagonal.

indifferent point—in a phase diagram, a maximum point, or minimum point, that is, a composition and temperature, or pressure, at which congruent transformation occurs.

indigenous (endogenous) inclusion—a nonmetallic material that precipitates from the melt. (See **inclusions.**)

inertial loading—See **impact loading**.

inflection point—position on a curved line, such as a phase boundary, where the direction of curvature is reversed.

infrared—invisible light and heat radiation, adjacent to the red end of the visible spectrum, with wavelengths from 700 to about 3000 nm (nanometres).

ingot—cast metal in a form intended for subsequent fabrication.

ingot scum—slag, dross, or oxidation appearing on the top surface of ingots during pouring, which, when entrapped, is a source of inclusions.

indices—See **Miller indices**.

indigenous inclusions—See **deoxidation products**.

inelastic electron scatter—See **incoherent electron scatter**.

instantaneous coefficient of thermal expansion —See **coefficient of thermal expansion**.

integral tripack—See **color film: monopack**.

intensifying screen—a sheet of a substance which emits visible light or X-rays or photoelectrons, or combinations of these, under the action of X-rays, thus enhancing the darkening of a film placed in contact with it.

intensity (*X-rays***)—**the energy per unit of time of a beam per unit area perpendicular to the direction of propagation.

intensity of scattering—the energy per unit time per unit area of the general radiation which is diffracted by matter. Its value depends upon the scattering power of the individual atoms of the material, upon the scattering angle, and upon the wavelength of the radiation.

intercept method—See **Heyn method**.

interception count—the number of particles (or clusters of particles) of a phase or constituent of interest that are crossed by the lines of a test grid.

intercrystalline cracks—cracks or fractures that occur between the grains or crystals in a polycrystalline aggregate.

interdendritic—located within the branches of a dendrite or between the boundaries of two or more dendrites.

interdendritic porosity—voids occurring between the dendrites in cast metal.

interference—the effect of a combination of wave trains of various phases and amplitudes.

intergranular corrosion—a preferential attack at the grain boundaries.

intermediary plane—any plane in a microscope where a real image of a specimen is formed. Reticles can be inserted at intermediary planes for superposition on the image.

intermediate image—any image of an object formed by a lens other than the final projector lens.

intermediate phase—in a chemical system, a distinguishable homogeneous substance whose composition range of existence does not extend to any of the pure components of the system.

intermetallic phases—compounds, or intermediate solid solutions, containing two or more metals, which usually have characteristic properties and crystal structures different from those of the pure metals or the terminal solid solutions.

internal oxidation—preferential oxidation of certain components or phases within the bulk of a solid metal.

internal seam—See **stepdown test**.

interplanar distance—the perpendicular distance between adjacent parallel lattice planes.

interpupillary distance—spacing between the pupils of the eyes; eyepieces on binocular microscopes should be set at this distance for comfortable and accurate viewing.

intersection count—the number of boundaries between the matrix phase and the phase or constituent of interest that are crossed by the lines of a test grid. For isolated particles in a matrix, the number of feature intersections will equal twice the number of feature interceptions.

intracrystalline cracking—See **transcrystalline cracking**.

invariant equilibrium—a stable state amongst a number of phases exceeding by two the number of components in the system and in which more of the external variables (pressure, temperature, or concentrations) may be varied without causing a decrease in the number of phases present.

invariant point—a point defined by the unique values of temperature, pressure, and concentrations in a system with the maximum number phases which can coexist in equilibrium.

inverse rate curve—in thermal analysis, the curve that is obtained when the length of time required by the specimen to pass through successive and constant intervals of temperature is plotted against the temperature.

inverse segregation—a concentration of low melting constituents in those regions in which solidification first occurs.

inverted microscope—a microscope so arranged that the line of sight is directed upwards through the objective to the object.

ionization chamber—a device for the measurement of radiation intensity by means of determining the degree to which the radiation ionizes a gas.

ionization method—a method of X-ray diffraction in which the intensity of the diffracted beam is measured by means of an ionization chamber.

ionization vacuum gage—an indicating device used in vacuum systems to determine the pressure of the residual gas

in a system by measuring the positive ion current produced in the process of ionization in an electrical field.

isobar—section, at constant pressure through a phase diagram.

isochor—in a phase diagram, a section, or contour, at constant volume.

isometric—a crystal form in which the unit dimension on all three axes is the same.

isomorphous—having the same crystal structure; usually referring to intermediate phases which form a continuous series of solid solutions.

isomorphous system—a complete series of mixtures in all proportions of two, or more, components, wherein unlimited mutual solubility exists in both the liquid and solid states.

isopleth—in a ternary, or higher order, temperature-concentration, or pressure-concentration, phase diagram, a (vertical) two-dimensional section, having a linear composition series along one axis and temperature, or pressure, along the other axis.

isotherm—section, at constant temperature, through a phase diagram.

isotropic—having the same value for a property in all directions.

isotropy—the condition of having the same values of properties in all directions.

Jeffries' method—a method for determining grain size based on counting grains in a prescribed area. See Test Methods E112.

Jeffries' multiplier—a factor used in the Jeffries' method for grain size determinations. See Test Methods E112.

K radiation—characteristic X-rays produced by an atom when a vacancy in the *K* shell is filled by one of the outer electrons.

K series—the set of X-ray wavelengths making up *K* radiation.

Kellner eyepiece—a positive eyepiece consisting of an achromatic eyelens and a single collective, in which the image plane and field diaphragm is external and near the collective.

Kikuchi lines—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.

knife edge pivot—a type of pivot or hinge in which the motion occurs through the rotation of a knife edge resting on a plane or a vee notch.

Knoop—See **micro penetration tester**. In a more restricted sense, a type of diamond hardness indenter having edge angles of 172° 30 min, and 130°.

Knudsen vacuum gage—an absolute manometer based on the principle of the transfer of momentum from a hot to a cold surface by gas molecules as in a radiometer.

Koehler illumination—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.

Konowalow's law—the vapor of a binary mixture contains the larger proportion of that component, which, upon addition to the liquid, will raise its vapor pressure.

lamination—imperfection in flat products resulting from the presence of voids or inclusions aligned approximately parallel to the worked surface.

lap—(*1*) a surface imperfection on worked metal caused by folding over a fin overfill, or similar surface condition and then impressing this into the surface by subsequent working without welding it.

(*2*) A flat surface which holds an abrasive for polishing operations.

lapping—the abrasive removal of material using graded abrasive particles in a loose form as in a liquid slurry on a platen.

latitude—when the photographic process is represented by an H and D curve, the latitude is the projection on the exposure axis of that part of the curve which approximates a straight line within the tolerance permitted for the purpose at hand.

lattice—(*1*) a space lattice is a set of equal and adjoining parallelopipeds formed by dividing up space by three sets of parallel planes, the planes in any one set being equally spaced. There are seven ways of so dividing space, corresponding to the seven crystal systems. The unit parallelopiped is usually chosen as the unit cell of the system.

(*2*) a point lattice is a set of points in space so located that each point has identical surroundings. There are fourteen ways of so arranging points in space, corresponding to the 14 Bravais lattices.

lattice parameter—the term is used for the fractional coordinates x, y, z of lattice points when these are variable. Also used to indicate the lengths of the axes a, b, c, and their included angles α, β, γ.

Laue equations—the three simultaneous equations which state the conditions which must be met for diffraction from a three-dimensional network of diffraction centers.

Laue method (for crystal analysis)—a method of X-ray diffraction employing a beam of white radiation, a fixed single crystal specimen and a flat photographic film usually normal to the incident beam. If the film is located on the same side of the specimen as the X-ray source, the method is known as the back reflection Laue method, if on the other side as the transmission Laue method.

layer lattice—a type of structure found in crystals which tend to form in thin sheets.

leaded—characteristic of a metallic body containing metallic lead in dispersed form.

Le Chatelier's theorem—if a system in equilibrium is subjected to a constraint by which the equilibrium is altered, a reaction takes place which opposes the constraint, that is, one by which its effect is partially annulled.

ledeburite—intimate mixture of austenite and cementite in metastable equilibrium, formed on rapid cooling during the eutectic reaction in alloys of iron and carbon containing greater than 2 percent but less than 6.67 percent carbon. Further slow cooling causes decomposition of the austenite into ferrite and cementite (pearlite) as a result of the eutectoid reaction.

lever principle—in a phase diagram, the relative proportions of the conjugate phases, at a stated value of temperature and pressure, or both, is such that a state of mechanical balance would obtain, if the corresponding weight of each phase were placed upon its composition point upon the tie-element (tie-line, tie-triangle, etc.) and the fulcrum were located at the gross composition point of the mixture.

lightfield illumination—See **brightfield illumination**.

light filter—See **color filter**.

limited solid solution—a crystalline miscibility series whose composition range does not extend all the way between the components of the system, that is, the system is not isomorphous.

lineage structure—orientation deviations, of the order of minutes or a few degrees at most, from perfect alignment of the crystal axes of parallel arms of a dendrite.

linear magnification—See **magnification**.

line focus (in X-ray tubes)—a long-narrow focal spot.

line indices—the Miller indices of the set of planes producing a diffraction line.

liquidus—the locus of points in a phase diagram, representing the temperature, under equilibrium conditions, at which each composition in the system begins to freeze during cooling, or completes melting during heating.

live field—in video-based automatic image analysis, the visible, real-time gray level image from the television camera.

longitudinal direction—that direction which is parallel to the direction of maximum elongation in a worked material. (See also **cross direction**).

lot—a unit of material processed at one time and subjected to similar processing variables.

lower critical point—in a phase diagram, a specified value of composition, temperature and pressure or combinations thereof occurring as a minimum in temperature, or pressure, for the coexistence of two, or more, conjugate phases and at which the conjugate phases become identical.

low reflecting coating—a dielectric coating applied to an air-glass surface to reduce light reflection to a minimum.

L-radiation—characteristic X-rays produced by an atom when a vacancy in the L-shell is filled by one of the outer electrons.

L-series—the set of X-ray wavelengths making up L-radiation.

Lüder's lines—markings which appear on the surface of metals stretched past the yield point. The markings are approximately parallel to the direction of maximum shear stress and essentially independent of crystal orientation; also called stretcher strains, flow figures, Hartmann lines.

macroetch—controlled etching of the surface of a metallic specimen, intended to reveal a structure which is visible at low magnifications (not usually greater than 10 times).

macrograph—a graphic reproduction of an object, slightly reduced in size, unmagnified, or magnified ten diameters or less (photomacrograph).

magnetic alignment—See **alignment**.

magnetic lens—a device for focussing an electron beam by means of a magnetic field.

magnetic shielding—in electron microscopy, shielding for the purpose of preventing extraneous magnetic fields from affecting the electron beam in the microscope.

magnetic transformation—an intensive property change from a ferromagnetic to a paramagnetic state, or the reverse, which occurs in certain solid materials under applied pressure and temperature, or both. (See also **Curie point**.)

magnification—a ratio of the size of an image to its corresponding object. This is usually determined by linear measurement.

martensite—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.

martensitic—a plate-like constituent having a similar appearance and mechanisms of formation to that of martensite.

mass-absorption coefficient—See **absorption coefficient**.

mass scattering coefficient—that part of the mass absorption coefficient due to scattering.

matrix—the continuous phase.

maximum curve—in a phase diagram, a univariant line, tracing the meetings of a pair of bivariant surfaces at intermediate composition and coinciding with their highest temperature at each pressure level, or their highest pressure

at each temperature level; congruent transformation occurs everywhere along a maximum curve.

maximum point—that composition and temperature, or pressure, at which a heterogeneous equilibrium occurs at its highest temperature, or pressure, when this does not coincide with one of the composition limits of the equilibrium, that is, when it occurs at an intermediate composition; the equilibrium becomes congruent (univariant) at the maximum point.

maximum sublimation point—in a PT phase diagram, the highest pressure and temperature at which a solid species of intermediate composition may exist in equilibrium with vapor of identical composition.

McQuaid-Ehn grain size—the austenitic grain size developed in steels by carburizing at 1700°F (927°C) followed by slow cooling. See Test Methods E112.

measurement uncertainty—an estimate of potential inaccuracies in a measured or derived quantity based on explicit evaluation and combination of all sources of errors. Note - Quantitative uncertainty estimates are typically given in the form of variances (or standard deviations) and covariances (or correlations) derived from statistical procedures combining random, systematic, and calculational (modeling) uncertainties.

measuring junction—the junction of a thermocouple placed at a location where an unknown temperature is to be measured or where an established temperature is to be maintained. When the measuring junction is at a higher temperature than the reference junction it is commonly called the hot junction.

mechanical alignment— See **alignment**.

mechanical stage—a device provided for adjusting the position of a specimen, usually by translation in two directions at right angles to each other.

mechanical twins—See **twin bands**.

melting point—in a phase diagram, the temperature at which the liquidus and solidus coincide at an invariant point.

melting pressure—at a stated temperature, the pressure at which the solid phases of an element, or congruently melting compound, may coexist at equilibrium with liquid of the same composition.

melting temperature—at a stated pressure, the temperature at which a solid phase of an element, or congruently melting compound, may coexist at equilibrium with liquid of the same composition.

membrane—any thin sheet or layer.

metallography—that branch of science which relates to the constitution and structure, and their relation to the properties, of metals and alloys.

metal shadowing—See **shadowing**.

metastable—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.

metatectic equilibrium— See **peritectoid equilibrium**.

microcharacter—See **micro penetration tester**.

microcut—the scratch made by a microcharacter test.

micrograph—a graphic reproduction of an object as seen through the microscope or equivalent optical instrument, at magnifications greater than ten diameters. (**photomicrograph**).

microindent—See **indentation**.

micrometer eyepiece—an eyepiece that has a scale permanently positioned in its focal plane, thus, in effect, superimposing the scale on the image of the field being observed.

micro penetration hardness—the hardness number obtained by use of a low load tester whose indentation is usually measured with a high power microscope.

micro penetration tester—a testing machine capable of applying low loads, usually in the range from 1 g to 5 kg to form an indentation or a scratch or both, as a basis for measuring hardness. Typical names associated with commercial testers are Bergsman, Eberbach, Knoop, Microcharacter, Tukon, Vickers, etc.

microphotograph—a microscopically small photograph.

microporosity—extremely fine porosity in castings.

microscope—an instrument capable of producing a magnified image of a small object.

microstructure—the structure of a suitably prepared specimen as revealed by a microscope.

Miller-Bravais indices—indices used for the hexagonal system which involve the use of a fourth axis a_3, coplanar with and at 120° to a_1 and a_2.

Miller indices (for lattice planes)—the reciprocals of the fractional intercepts which a plane makes on the three axes. The symbols are (*hkl*).

minimum curve—in a phase diagram, a univariant line tracing the meeting of a pair of bivariant surfaces at intermediate composition and coinciding with their lowest temperature at each pressure level, or their lowest pressure at each temperature level; congruent transformation occurs everywhere along a minimum curve.

minimum point—that composition and temperature, or pressure, at which a heterogeneous equilibrium occurs at its lowest temperature, or pressure, when this does not coincide with one of the composition limits of the equilibrium, that is, when it occurs at an intermediate composition; the equilibrium becomes congruent (univariant) at the minimum point.

mirror illuminator—a thin, half-round opaque mirror interposed in a microscope for the purpose of directing an intense oblique beam of light to the object. The light incident on the object passes through one half the aperture of the objective

and the light reflected from the object passes through the other half aperture of the objective.

miscibility gap—a region of multi-phase equilibrium; commonly applied to the specific case in which an otherwise continuous series of liquid, or solid, solutions is broken, over a limited temperature range, by the intrusion of a two phase field that terminates at a critical point. See **binodal curve**.

mixed grain size—See **duplex grain size**.

molecular replica— See **replica**.

monochromatic (homogeneous)—of the same wavelength.

monochromatic objective—an objective, usually made of fused quartz, which has been corrected for use only with monochromatic light.

monochromator (X-rays)—a device for producing monochromatic radiation from heterochromatic radiation. It usually consists of a crystal so arranged as to diffract one wavelength of particularly high intensity, such as the characteristic, out of a beam of mixed white and characteristic radiation.

monoclinic—having three axes of any length with two included angles equal to 90° and one included angle not equal to 90°.

monopack—See **color film**.

monotectic equilibrium—a reversible binary univariant transformation in which a liquid phase, that is stable only at higher temperatures, decomposes, with lowering temperature, into a new liquid phase and a solid phase, for example: $L_1 = L_2 + \alpha$.

monotectic point—the composition and temperature in a binary system at which exists a liquid that is capable of univariant decomposition, with lowering temperature, into another liquid phase and a solid phase.

monotropic transformation—a nonreversible metastable phase change.

morphology—the shape characteristics of a structure; the form and orientation of specific phase or constituent.

mosaic crystal—an imperfect single crystal composed of regions each very slightly disoriented with respect to its neighbor.

mosaic structure—the structure of a material containing mosaic crystals.

multicomponent system—the complete series of compositions produced by mixing, in all proportions, two or more components.

multiplicity factor—a factor used in calculating the intensity of diffraction from a polycrystalline specimen. It is equal to the number of sets of planes of the same family.

multivariant—having two or more degrees of freedom.

mythical image—the assumed intersections of the extended sides of a microindentation which is established in order that a true diagonal can be approximated.

negative distortion— See **distortion**.

negative eyepiece—an eyepiece in which the real image of the object is formed between the lens elements of the eyepiece.

negative, photographic—a sensitized plate or film which has been exposed in a camera and which upon development has the lights and shades inverse to those of the original subject. The plate or film does not become a negative until it is exposed, after which it may be an undeveloped or a developed negative.

negative print—a photograph having approximately the opposite rendition of light and shade as the original subject.

negative replica—See **replica**.

network structure—a structure in which one constituent occurs primarily at the grain boundaries, thus partially or completely enveloping the grains of the other constituents; on a two-dimensional section cut through such a structure, the grain boundary constituent will appear as a network.

Neumann bands—See **twin bands**.

neutral body—a comparison piece used in the differential method of thermal analysis, which has nearly the same thermal properties as the test specimen, and which produces no heat effects within the temperature range through which the specimen is being tested. See Practice E80.

Nicol prism—a prism, used for polarizing or analyzing light, made by cementing together, with Canada balsam, two pieces of calcite in such a way that the extraordinary ray from the first piece passes through the second piece while the ordinary ray is reflected to the side into an absorbing layer of black print. When two Nicol prisms are crossed, therefore, no light passes through.

nitride-carbide inclusion types—a compound with the general formula $M_x(C, N)_y$ observed generally as colored idiomorphic cubic crystals, where *M* includes Ti, Cb, Ta, Zr.

nonmetallic inclusions—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 (See **exogenous inclusions**).

normal direction—that direction which is perpendicular to the plane of working in a worked material. (See **cross direction**).

normal segregation—a concentration of alloying components or constituents that have lower melting points in those regions which are the last to solidify.

numerical aperture (NA)—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.

objective aperture—See **aperture**.

object evaporation—See **shadowing**.

oblique illumination—nonspecular illumination under which the light impinges at an oblique angle to the optical axis. (See **conical illumination; diffuse illumination; darkfield illumination**.)

ocular micrometer—a glass disk, of a diameter which permits introducing it into standard oculars, upon one surface of which a fine scale is engraved accurately.

optical pyrometer—an instrument with the temperature of an object is determined by comparing its brightness at some fixed wavelength with that of a standardized source.

order (in X-ray reflection)—the factor *n* in the Bragg equation (see **Bragg equation**). In X-ray reflection from a crystal, the order is an integral number which is the path difference measured in wavelengths between reflections from adjacent planes.

order-disorder transformation—a phase change among two solid solutions having the same crystal structure but in which the atoms of one phase, the disordered one, are randomly distributed and in the other, the different kinds of atoms occur in a regular sequence upon the crystal lattice, that is, in an ordered arrangement.

ordered structure—that crystal structure of a solid solution in which the atoms of different elements seek preferred lattice positions.

order of a system—the number of components; for example, a system of binary order is made up of two components.

orientation—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 non-homogeneous properties of the specimen.

orthochromatic—(*1*) of, pertaining to, or producing tone values (of light or shade) in a photograph, corresponding to the tones of nature.

(*2*) photographic use; designating a film made sensitive to green and blue, but not red, light.

orthorhombic—having three mutually perpendicular axes of unequal lengths.

overdrawn structure—a condition, sometimes found to exist in very heavily cold-worked rods or wires. (**cupping**). Cupping is overdrawn material, but the converse is not true.

overheating—(*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.

oxidation grain size—(*1*) grain size determined by holding a specimen at a suitably elevated temperature in a mildly oxidizing atmosphere. The specimen is polished before oxidation and etched afterwards.

(*2*) refers to the method involving heating of polished steel specimen to a specified temperature, followed by quenching and repolishing. The grain boundaries are sharply defined by the presence of iron oxide. Grain size is expressed as an ASTM Number.

oxide film replica—See **replica**.

oxide type inclusions—oxide compounds occurring as nonmetallic inclusions in metals usually as a result of deoxidizing additions. In wrought products, that is, steel, they may occur as a "stinger" formation composed of distinct granular or crystalline appearing particles.

panchromatic—sensitive, as a film or plate, to light of all hues.

parallax factor (used in electron stereomicroscopy)—parallax factor (*f*) is the rate of change of elevation with respect to parallax:

$f = dx/dy = \csc \sigma/2M \times 10^3$ μm/mm

x = elevation

y = parallax, the apparent lateral displacement of an image point.

where σ is the stereo angle and *M* is the final magnification of the image.

parameter (*in crystals*)—See **lattice parameter**.

partial pressure—the contribution of one component of a system to the total pressure of its vapor at a specified temperature and gross composition.

partition coefficient—when, to a polyphase mixture there is added a definite quantity of a new component that is insufficient to bring about a phase change, the proportioning of the new component among the several phases at equilibrium may be expressed by means of a ratio known as a partition coefficient; since the ratio often changes very little over small ranges of variation in the amount of the added component, it is customary simply to refer to the partition coefficient of the added component without reference to the quantity of the addition, provided the latter is small.

pattern—See **diffraction pattern**.

pearlite—a metastable microstructure formed, when local austenite areas attain the eutectoid composition, in alloys of iron and carbon containing greater than 0.025 percent but less than 6.67 percent 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.

pearlite colony—a circumscribed aggregate within which lamellae of corresponding phases have the same orientation.

pearlite nodule—cluster of wedge-shaped pearlite colonies.

pearlitic structure—a microstructure resembling that of the pearlite constituent in steel, therefore, a lamellar type of structure of varying degrees of coarseness.

pellicle mirror—a thin transparent membrane used in place of a transparent flat glass disk of a "plane glass illuminator."

penetrator—See **indenter**.

peritectic equilibrium—a reversible univariant transformation in which a solid phase, that is stable only at lower temperature, decomposes into a liquid and a solid phase that are conjugate at higher temperature, or the reverse; for example: $\alpha + L = \beta$, $\alpha + \beta + L = \gamma$, etc.

peritectoid equilibrium—a reversible univariant transformation in which a solid phase, that is stable only at low temperature, decomposes with rising temperature into two or more conjugate solid phases; for example: $\alpha + \beta = \gamma$, $\alpha + \beta + \gamma = \delta$, etc.

permanent magnet lens—an electron lens consisting of permanent magnets.

petrographic examination—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.

phase—a physically homogeneous, mechanically separable portion of a material system.

phase contrast microscopy—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.

phase diagram—See **constitutional diagram**.

phase rule—the maximum number of phases (P) that may coexist at equilibrium is equal to 2, plus the number of components (C) in the mixture, minus the number of degrees of freedom (F); $P + F = C + 2$.

Philips (Penning) vacuum gage—a sensitive cold cathode ionization gage in which the electron path length, and therefore the number of ionizing collisions, is increased by means of a magnetic field. Also known as a cold-cathode discharge gage.

photographic density—See **density**.

photomacrograph—a macrograph made by photographic means.

photomicrograph—a micrograph made by photographic means.

physical objective aperture—See **aperture, electron**.

pincushion distortion—See **distortion**.

pinholes—very small holes; sometimes found as a type of porosity in a casting because of microshrinkage or of gas evolution during solidification; or, in wrought products, due to removal of inclusions or microconstituents during macroetching of transverse sections. In photography, a very small circular aperture.

pinhole eyepiece—an eyepiece, or a cap to place over an eyepiece, which has a small central aperture instead of an eye lens. Used in adjusting or aligning microscopes.

pinhole ocular—See **pinhole eyepiece**.

pinhole system—a group of two or more pinholes arranged to define a beam.

pirani vacuum gage—a thermal conductivity or hot-wire gage in which the temperature of an electrically heated fine wire varies as the thermal conductivity of the residual gas. The wire has a high temperature coefficient of electrical resistance and the change in resistance is usually measured in a bridge circuit. (See **thermocouple vacuum gage**.)

pixel (picture element)—smallest spatial unit of an image.

planar grinding—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.

plane (crystal)—an idiomorphic face of a crystal. Any atom-containing plane in a crystal.

plane glass illuminator—a thin transparent flat glass disk interposed in a microscope or a lens imaging system for the purpose of directing light to the object without causing a reduction of the useful aperture of the lens system.

plane of working—the plane of maximum area extension.

planimetric method— See **Jeffries' method**.

plastic replica—See **replica**.

plate cassette—See **cassette**.

plate chamber—the chamber within the vacuum system of an electron microscope in which is placed the plate cassette.

polarized light illumination—a method of illumination in which the incident light is plane polarized before it impinges on the specimen.

polarizer—a Nicol prism, polarizing film, or similar device into which normal light passes and from which polarized light emerges.

pole figure (for crystalline aggregates)— a graphical representation of the crystal orientations present in an aggregate.

pole piece—a part of a magnetic electron lens made of a magnetically permeable material for the purpose of concentrating and shaping the magnetic field within the lens.

pole piece spacer—the central part of a magnetic electron lens pole piece assembly made of nonmagnetic material for the purpose of rigidly defining the separation of the pole pieces of a lens. The length of the spacer affects the strength and shape of the magnetic field in the lens.

polishing—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.

polycrystalline—characteristic of an aggregate composed of more than one, and usually of a large number, of crystals.

polymorphic substance—an element, or compound, capable of stable existence in different temperature and pressure ranges in two, or more, different crystalline states.

polynary system—See **multicomponent system**.

porosity—holes in a solid, not necessarily connected.

positive distortion— See **distortion**.

positive eyepiece—an eyepiece in which the focal plane is external to its lenses.

positive, photographic—a photograph having approximately the same rendition of light and shade as the original subject.

positive replica—See **replica**.

positive transparency—a photographic print made on a transparent base from a negative. In electron microscopy this is used as an intermediate step to prepare a negative print.

potentiometer—an instrument for the measurement of electromotive force by balancing against it an equal and opposite electromotive force across a calibrated resistance carrying a definite current. Potentiometers can be made manual or with automatic self-balancing features.

powder method—any method of X-ray diffraction involving a polycrystalline and preferably randomly oriented powder specimen and a narrow beam of monochromatic radiation.

precipitation—separation of a new phase from solid, liquid, orgaseous solutions, usually with changing conditions of temperature or pressure, or both.

preferred orientation—a condition of polycrystalline aggregate in which the crystal orientations are not distributed at random.

preshadowed replica— See **replica**.

primary (X-ray)—the beam incident on the sample.

primary crystals—the first type of crystals that separates from a melt on cooling.

primary extinction—a decrease in intensity of a diffracted X-ray beam caused by perfection of crystal structure extending over such a distance (about 10^{-4} cm or greater) that interference between multiply reflected beams inside the crystal causes a decrease in the intensity of the externally diffracted beam.

principal point—a point on the axis of symmetry of a lens or lens system from which any ray entering the lens or lens system will emerge in a parallel direction.

prism illuminator—a 45 to 90° prism interposed in a microscope for the purpose of directing an intense oblique beam of light to the object. The prism illuminator utilizes only one half the aperture of the microscope as does the mirror illuminator with an attending loss of resolution over that obtainable with either a plane glass illuminator or a pellicle mirror.

process anneal—a heat treatment used to soften metal for further cold working; in ferrous sheet and wire industries, heating to a temperature close to but below the lower limit of the transformation range and subsequently cooling for working; in the nonferrous industries, heating above the recrystallization temperatures at a time and temperature sufficient to permit the desired subsequent cold working.

proeutectoid carbide—primary crystals of cementite formed directly from the decomposition of austenite exclusive of that cementite which results from the eutectoid reaction.

proeutectoid ferrite—primary crystals of ferrite formed directly from the decomposition of austenite exclusive of that ferrite which results from the eutectoid reaction.

program controller—a device which can automatically execute a pre-determined schedule of control.

projection distance—distance from the eyepiece to the image screen.

projection lens—the final lens in the electron microscope corresponding to an ocular or projector in a compound light microscope. This lens forms a real image on the viewing screen or photographic film.

protection tube—a tube made of a specially selected material which can be used to protect a thermocouple from adverse effects of the environment.

pseudobinary—a term of indefinite meaning, sometimes used synonymously with "quasibinary," sometimes used to designate an "isopleth."

pseudomonotropy—an irreversible solid state transformation which occurs below the melting points of both the stable and metastable solid states.

pseudoreplica—See **replica**.

P-T diagram—a two-dimensional, graphical representation of phase relationships in a system of any order, by means of the pressure and temperature variables.

P-T-X diagram—a three-dimensional, graphical representation of the phase relationships in a binary system, by means of the pressure, temperature and concentration variables.

pull–out, *n*—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.

P-V diagram—a graphical representation of the variation of the specific volume of a substance, with change in pressure.

P-V-T diagram—a three-dimensional, graphical representation of a surface, describing the variation of the specific volume of a substance, with independent change of pressure and temperature.

P-X diagram—a two-dimensional, graphical representation of the isothermal phase relationships in a binary system; the coordinates of the graph are pressure and concentration.

P-X projection—a two-dimensional, graphical representation of the phase relationships in a binary system produced by making an orthographic projection of the phase boundaries of a P-T-X diagram upon a pressure-concentration plane.

pyrometer—an instrument for measuring temperatures (see **pyrometry**). An autographic or recording pyrometer automatically measures and records temperatures.

pyrometry—the measurement of temperatures: for example, by measuring the electrical resistance of wire, the thermoelectric force of a couple, the expansion of solids, liquids or gases, the specific heat of solids, or the intensity of radiant energy per unit area.

quadrivariant equilibrium—a stable state among a number of conjugate phases equal to two less than the number of components, that is, having four degrees of freedom.

quadruple curve—in a P-T diagram, a line representing the sequence of pressure and temperature values along which three conjugate phases occur in univariant equilibrium.

quadruple point—in a P-T diagram the pressure and temperature at which four conjugate phases occur in invariant equilibrium.

quarter wave plate—a device used with a polarizer and analyzer designed to produce circularly polarized light.

quasi-binary system—in a ternary or higher order system, a linear composition series between two congruent substances, wherein all equilibria, at all temperatures or pressures, involve only phases having compositions occurring in the linear series, so that the series may be represented as binary on a phase diagram.

quasi-isotropic—See **isotropic.**

quasi-ternary system—in a quaternary or higher order system, a planar composition series among three congruent substances, wherein all equilibria, at all temperatures and pressures, involve only phases having compositions occurring upon the plane, so that they may be represented completely upon a ternary phase diagram.

quaternary system—the complete series of compositions produced by mixing four components in all proportions.

quenching crack—a crack formed as a result of thermal stresses produced by rapid cooling from a high temperature—not to be confused with fire crack.

radiation pyrometer—an instrument for determining temperatures by measuring the radiance (radiant energy per unit area) from an object.

random orientation—a condition of a polycrystalline aggregate in which the constituent crystals have orientations completely random with respect to one another.

range, exposure—See **exposure scale.**

reaction isotherm—in a temperature-concentration phase diagram, a tie-element at constant temperature, representing univariant equilibrium among three or more phases.

recalescence—the increase in temperature which occurs after undercooling because the rate of liberation of heat during transformation of a material exceeds the rate of dissipation of heat.

reciprocal lattice—a lattice of points each of which represents a set of planes in the crystal lattice, such that a vector from the origin of the reciprocal lattice to any point is normal to the crystal planes represented by that point and has a length which is the reciprocal of the plane spacing.

recrystallized grain size—(*1*) the grain by heating following cold work where the time and temperature are so chosen that, while recrystallization is complete, essentially no grain growth has occurred.

(*2*) in aluminum and magnesium alloys, the grain size after recrystallization, without regard to grain growth or the recrystallization conditions.

recrystallization—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.

reference junction—that junction of a thermocouple which is held at a known temperature.

reference junction correction—a correction in terms of electromotive force (millivolts) to be applied to the electromotive force generated by a thermocouple to compensate for the difference between the actual temperature of the reference junction and that used as the basic reference junction temperature in standard conversion tables.

reference material—a material or substance, one or more properties of which are sufficiently well established to be used for the assessment of a measurement method or for assigning values to materials.

reference standard—a material or device whose properties are determined by comparison to another standard, such as a certified reference material.

reflection **(***X-ray***) —**See **diffraction.**

reflection method—the technique of producing a diffraction pattern by X-rays or electrons which have been reflected from a specimen surface.

refractive index (electrons)—the ratio of electron wavelength in free space to its wavelength in a material medium.

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 nitrocellulose.

(*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.

replicate—in electron microscopy, to reproduce by means of a replica.

resistance thermometer—an instrument for determining temperature by measuring the electrical resistance of a standardized material exposed to that temperature.

resolution—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 (see **resolving power** and **shape resolution**). The theoretical limit of resolution is determined from the equation:

$$d = 0.61\,\lambda/(n \sin A.A./2) \quad (7)$$

where:

d = minimum distance between object points observed as distinct points in the image.

λ = wavelength of the radiation employed.

n = the minimum refractive index of the media between the object and the objective lens.

$A.A.$ = the angular aperture.

resolving power—the ability of a given lens system to reveal fine detail in an object. (See also Resolution.)

retardation plate—a plate placed in the path of a beam of polarized light for the purpose of introducing a difference in phase. Usually quarter-wave or half-wave plates are used, but if the light passes through them twice the phase difference is doubled.

reticle—a system of lines, circles, dots, cross hairs or wires, or some other pattern, placed in the eyepiece or at 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, see **graticule**).

retrograde condensation—where the critical point of multicomponent liquid-vapor equilibrium occurs below the maximum in temperature and pressure of the two-phase region, a sequence of increasing pressure change, at a temperature between the temperature maximum and the critical point, will cause a partial condensation of the vapor to liquid and then a full return to the vapor state, called retrograde condensation.

retrograde vaporization—the inverse of retrograde condensation.

reversal plate, film, or paper—a photographic material which, after exposure to a subject, is processed to give a positive reproduction without transfer of the image to another sheet material.

reversed print—a print prepared from a positive transparency. (See also **negative print**.)

reversed transparency— See **positive transparency.**

rhombohedral—having three equal axes, with the included angles equal to each other but not equal to 90°.

rigid grinding disk—a non-fabric support surface, such as a composite of metal/ceramic or metal/polymer, charged during use with an abrasive (usually 6 to 15 micrometer diamond particles) and used for grinding operations in a metallographic preparation.

ridging indentation—a hardness indentation around which metal has been piled up above the plane of the specimen.

rolling direction (*in rolled metals*)**—**See **longitudinal direction.**

saddle curve—in a phase diagram, the locus of a series of maximum points which itself passes through a minimum value.

saddle point—the minimum point on a saddle curve, which is a univariant point, a composition of congruent melting.

saturated gun—a self-biased electron gun in which electron emission is limited by space charge rather than filament temperature.

scanning microscope—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.

scattering (X-ray)—a general term which includes both Compton and coherent scattering.

scratch—in micro-indentation hardness testing, a mark or groove cut in the specimen by moving a loaded indenter across the surface.

screen lens—an electrostatic electron lens consisting of a combination of screens or foils at different potentials.

screen plate or film— See **color film.**

screw stock—metal in the form of wire or rod, usually a free-machining alloy used for automatic screw machine work.

seam—an unwelded fold or lap on the surface of a metal which appears as a crack, usually the result of defects in casting or working which have not welded shut.

secondary (concerning X-rays)—the X-rays emitted by a specimen irradiated by a primary beam.

secondary extinction—a decrease in the intensity of a diffracted X-ray beam caused by parallelism or near-parallelism of mosaic blocks in a mosaic crystal; the lower blocks are partially screened from the incident radiation by the upper blocks, which have reflected some of it.

section—in a phase diagram, a planar cut through a space diagram; sections are commonly isotherms, isobars or isopleths.

segregation—concentration of alloying elements in specific regions in a metallic object.

selenide-type inclusions— See **sulfide-type inclusions.**

self-balancing potentiometer—See **potentiometer.**

self-biased gun—an electron gun in which the cathode cap is biased with respect to the filament by means of a bias resistor through which the emission current flows between the filament and cap. This type of gun provides high intensity at low angular apertures. (See **biased gun, unbiased gun, saturated gun.**)

semiapochromatic objective—a compromise, in the correction for chromatic and spherical aberration, between achromatic and apochromatic objectives; frequently called fluorite objectives.

semiapochromatic objective lens—an objective lens with both longitudinal and spherical chromatic correction for green and blue. Should be used with green or blue filters.

semiautomatic image analyzer—a device which can detect and measure features of interest in an image but requires the operator to perform feature discrimination.

sensitive tint plate—a gypsum plate (better known as a red I or full wave plate), used with cross polarized light producing circularly polarized light. For anisotropic materials, colors are enhanced, for isotropic materials, a magenta hue is produced.

sensitivity, photographic—the degree to which a photographic material responds by a change in its chemical or physical state to the action of both light and chemical development. The sensitivity of a given photographic material varies with wavelength of the incident radiation. The average degree of response is commonly referred to as speed.

sensitometric curve— See **characteristic curve.**

series (in x-ray spectra)—the group of characteristic X-ray lines which results when a vacancy in one particular electron level is filled from outside levels. Thus, the K series lines are emitted when a K level vacancy is filled.

shadow angle—the angle between the line of motion of the evaporated atoms and the surface being shadowed. The angle is analogous to the angle of incidence in optics. May be specified as an arc tangent "a" so that "a" is in the ratio between the height of the object casting the shadow over the length of the shadow (see **shadowing**).

shadow cast replica—a replica which has been shadowed. (See also **shadowing.)**

shadowing—a process by which a metal or salt is deposited on a specimen at an angle (see **shadow angle**) from a heated filament in a vacuum to enhance image contrast by inhibiting the deposition of the shadowing material behind projections.

(*1*) *metal shadowing*—the enhancement of contrast in a microscope specimen by the vacuum deposition of a dense metal at an angle generally not perpendicular to the surface of the object.

(*2*) *oblique evaporation*—the condensation of evaporated material onto a substrate which is inclined to the direct line of the vapor stream in order to produce shadows.

shadow microscope—an electron microscope which forms a shadow image of an object using electrons emanating from a point source located close to the object.

shape resolution—an electron image exhibits shape resolution when a polygon can be recognized as such in the image. Roughly, the particle diameter (defined as the diameter of a circle of the same area as the particle) must exceed the resolution by a factor equal to the number of sides on the polygon.

shattering—a phenomenon observed in hardness testing in which fissures or subsurface cracks originate in a hardness indentation and spread to adjacent parts of the specimen.

shielding—in an electron-optical instrument, the protection of the electron beam from distortion due to extraneous electric and magnetic fields. Since the metallic column of the microscope is at ground potential, it provides electrostatic shielding. Magnetic shields may be made of a high permeability material.

shutter—a mechanical device which permits regulation of the time during which light is allowed to act on a light sensitive medium.

side centered—equivalent to end centered with a different choice of axes. (See **end centered.**)

sigma (σ)—solid phase found originally in binary iron-chromium alloys which is in stable equilibrium at temperatures below 820°C. Now used to identify any structure which possesses the same complex body-centered crystal structure.

silicate type inclusions—inclusions composed essentially of silicate glass, normally plastic at foraging and hot-rolling temperatures, which appear in steel in the wrought condition as small elongated inclusions usually dark in color under reflected light as normally observed.

simple (concerning lattices)—having similar atoms or groups of atoms separated by integral translations only.

sinking indentation—a hardness indentation around which the metal has been depressed below the plane of the specimen.

slip—translation of a portion of a crystal relative to the adjacent portion.

slip bands—See **slip lines.**

slip lines (slip bands)—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.

slip planes—in a given metal, slip occurs most easily along certain crystallographic planes. Hence, these planes are termed slip planes.

slit—a narrow aperture, usually rectangular in shape.

slit system—a group of two or more slits arranged to define a beam.

soft (X-rays)—of long wavelength.

solder embrittlement—reduction in ductility of a metal or alloy associated with local penetration by molten solder long grain boundaries.

solidification range—the temperature range between the liquidus and the solidus.

solidification shrinkage crack—a crack that forms, usually at elevated temperature because of the shrinkage stresses built up during solidification of a metal casting; a hot crack.

solid solution—a solid phase in which the composition and properties including lattice parameter can vary continuously without changing the crystal structure; a primary or terminal solid solution is limited by and has the crystal structures of a pure metal, a secondary or intermediate solid solution has the basic crystal structure of an intermetallic compound but does not necessarily include its stoichiometric composition.

solidus—the locus of points in a phase diagram, representing the temperature, under equilibrium conditions, at which each composition in the system begins to melt during heating, or completes freezing during cooling.

soller slit—a slit containing a set of thin, closely spaced, parallel metal plates used for the purpose of largely eliminating convergent and divergent rays.

solution—in a chemical system, a phase existing over a range of composition.

solvus—the locus of points in a phase diagram, representing the temperature, under equilibrium conditions, at which each composition of a solid phase becomes capable of coexistence with another solid phase, that is, a solid-solubility limit. Usually applied to the terminal solid solution.

sorbite (an obsolete and ill-defined term)—an aggregate of carbide and ferrite produced by tempering martensite at temperatures in the vicinity of 600 °C and which may be resolved readily at relatively low magnification (for example, 500X).

DISCUSSION—The term has also been applied to very fine pearlite that cannot be resolved with the light microscope at 500X.

source (X-rays)—the area emitting primary X-rays in a diffraction experiment. The actual source is always the focal spot of the X-ray tube but the virtual source may be a slit or pinhole, depending on the conditions of the experiment.

space charge aberration—an aberration resulting from the mutual repulsion of the electrons in a beam. This aberration is most noticeable in low-voltage, high-current beams. This repulsion acts as a negative lens causing rays which were originally parallel to diverge.

space lattice—See **lattice**.

spacing (*between lattice planes*)—See **interplanar distance**.

spatial grain size—the average size of the three-dimensional grains, as opposed to the more conventional grain size determined by a simple average of observations made on a cross section of the material.

specimen chamber (electron optics)—the compartment located in the column of the electron microscope in which the specimen is placed for observation.

specimen charge (electron optics)—the electrical charge resulting from the impingement of electrons on a nonconducting specimen.

specimen contamination (electron optics)— the contamination of the specimen caused by the condensation upon it of residual vapors in the microscope under the influence of electron bombardment.

specimen distortion (electron optics)— a physical change in the specimen caused by desiccation or heating by the electron beam.

specimen grid—See **specimen screen**.

specimen holder (electron optics)—a device which supports the specimen and specimen screen in the correct position in the specimen chamber of the microscope.

specimen screen (electron optics)—a disk of fine screen, usually 200-mesh stainless steel, copper, or nickel, which supports the replica or specimen support film for observation in the microscope.

specimen stage—the part of the microscope which supports the specimen holder and specimen in the microscope, and can be moved in a plane perpendicular to the optic axis from outside the column.

specimen stage controls—the external controls by means of which the stage can be moved.

specimen strain—a distortion of the specimen resulting from stresses occurring during preparation or observation. In electron metallography, strain may be caused by stretching during removal of a replica or during subsequent washing or drying. Also, electrical and thermal stresses caused by the electron beam may arise during observation.

spectrograph (X-ray)—an instrument for recording photographically at predetermined angles the results of diffraction experiments.

spectrometer (X-ray)—(*1*) an instrument similar to a spectrograph but employing a movable X-ray measuring device, such as a Geiger-Müller counter or ionization chamber, instead of a photographic film. The measuring device moves on a circle centered on the spectrometer axis.

(*2*) An instrument for recording, similar to the spectrograph, except that a Geiger-Müller counter, scintillation counter, proportional counter, or ionization chamber substitutes for the photographic recording.

speed (photographic or film) (see sensitivity)—a measure of the response of sensitivity of the material to light, often expressed numerically according to one of several systems, for example, H. and D., D.I.N., Scheiner, and American Standard speed.

spherical aberration—a lens defect in which image-forming rays passing through the outer zones of the lens focus at a distance from the principal plane different from that of the rays passing through the center of the lens.

spherical projection—a projection in which the orientation of a crystal plane is represented by the point where the plane normal intersects a sphere drawn with the crystal as the center.

spheroidite—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.

spinodal curve—a graphical representation of the realizable limit of the super-saturation of a solution.

sputtering—the production of specimens in the form of thin films by deposition from a cathode subjected to positive ion bombardment.

stage—a device for holding a sample in the desired position in the optical path.

stage micrometer—a graduated scale used on the stage of a microscope for calibration.

standard—1) a physical reference used as a basis for comparison or calibration;

2) a concept that has been established by authority, custom, or agreement to serve as a model or rule in the measurement of quality or establishment of a practice or procedure.

standard (hardness) block—a carefully prepared metal block used to calibrate hardness test machines.

standard grain-size micrograph—a micrograph taken of a known grain size at a known magnification, which is used to determine grain size by direct comparison with another micrograph or with the image of a specimen.

steadite—(*1*) ternary eutectic found in alloys of iron, carbon and phosphorus. In cast irons it consists of austenite, cementite and iron phosphide or austenite and iron-phosphide. If conditions are such that carbon is deposited as cementite, the three constituents of the eutectic are present. If, however, the carbon is deposited as graphite, that precipitated from the ternary eutectic crystallizes on existing flakes and the eutectic consists of two constituents only, namely, austenite and iron-phosphide.

(*2*) Binary eutectic found in alloys of iron and phosphorus consisting of ferrite and iron-phosphide.

stepdown test—a test involving the preparation of a series of machined steps progressing inward from the surface of a bar for the purpose of detecting by visual inspection internal laminations caused by inclusion segregates. See Practice E45.

stereo angle—one half of the angle through which the specimen is tilted when taking a pair of stereomicrographs. The axis of rotation lies in the plane of the specimen.

stereographic projection—the projection to a plane from a spherical projection, customarily using the South Pole as the eye point.

stereology—the study of mathematical procedures used to derive three-dimensional parameters describing a structure from two-dimensional measurements.

stereomicroscope—a light optical microscope that permits each eye to examine the specimen at a slightly different angle, thereby retaining its three-dimensional relationship.

stereoscopic micrographs—a pair of micrographs of the same area but taken from different angles so that the two micrographs when properly mounted and viewed reveal the structures of the objects in their three-dimensional relationships.

stereoscopic specimen holder—a specimen holder designed for the purpose of making stereomicrographs. It makes possible the tilting of the specimen through the stereo angle.

stress-corrosion crack—a crack which may be intergranular or transgranular depending on the material, resulting from the combined action of corrosion and stress, either external (applied) or internal (residual).

stringer—a single, high-aspect ratio, elongated inclusion, two or more elongated inclusions, or a number of small non-deformable inclusions aligned in a linear pattern due to deformation.

structure—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.

structure factor—the ratio of the amplitude of the wave scattered by all the atoms of a unit cell to the amplitude of the wave scattered by a single electron. Symbol = F.

sublimation pressure—at a stated temperature, that pressure at which congruent equilibrium between a solid substance and its vapor occurs.

sublimation temperature—at a stated pressure, that temperature at which congruent equilibrium between a solid substance and its vapor occurs.

submicroscopic—See **ultramicroscopic**.

substrate—(substratum) that which lies under; foundation.

sulfide-type inclusions—in steels, nonmetallic inclusions composed essentially of manganese iron sulfide solid solutions (Fe, Mn) S. They are characterized by plasticity at hot-rolling and forging temperatures and, in the hot worked product, appear as dove gray elongated inclusions varying from a threadlike to oval outline. Selenide type inclusions may behave similarly.

superlattice—See **ordered structure**.

symmetry—a property of a crystal in virtue of which equivalent lattice points can be brought into coincidence by operations such as rotation, inversion, or reflection. Such operations, are called symmetry operations or elements.

syntectic equilibrium—a reversible univariant transformation in which a solid phase, that is stable only at lower temperature, decomposes into two conjugate liquid phases that remain stable at higher temperature; for example: $L_1 + L_2 = \alpha$.

system (*crystal*)—See **crystal system**.

tape replica—See **replica**.

target (in X-ray tubes)—that part of an X-ray tube which the electrons strike and from which X-rays are emitted.

temper carbon—clusters of finely divided in malleable iron, that are formed as a result of decomposition of cementite, for example, by heating white cast iron to temperatures above the ferrite-austenite transformation temperature and holding at these temperatures for a considerable period of time (**graphite, nodular**).

tempered martensite—the decomposition products which result from heating martensite to temperatures below the ferrite austenite (Ae_1) transformation temper. Under the light microscope, darkening of the martensite needles is observed in the initial stages of tempering. Prolonged tempering at high temperatures produces spheroidized carbides in a matrix of ferrite. At the higher resolution of the electron microscope, the initial stage of tempering is observed to result in a structure containing a precipitate of fine epsilon iron carbide particles. At about 500°F (260°C), there is a transition to a structure of larger and elongated cementite particles in a ferrite matrix. With further tempering at higher temperature, the cementite particles become spheroidal, decreased in number, and increased in size.

terminal solid solution—in a multicomponent system, any solid phase, of limited composition range, which includes the composition of one of the components of the system.

ternary system—the complete series of compositions produced by mixing three components in all proportions.

tervariant equilibrium—a stable state among a number of conjugate phases equal to one less than the number of components, that is, having three degrees of freedom.

Tessar—trade name for a photographic objective made by combining a positive lens, a negative lens, and a doublet, which is used for making macrographs.

tetragonal—having three mutually perpendicular axes, two equal in length and unequal to the third.

texture (*cube*) —See **preferred orientation**.

texture (*deformation*)—See **preferred orientation**.

thermal arrest—See **arrest**.

thermal electromotive force—the voltage generated when one junction of two dissimilar metal wires is at a different temperature than the other junction.

thermal expansion—the increase in the dimensions or the volume of a body due to a change in temperature. (See **coefficient of thermal expansion**.)

thermionic cathode gun—(hot cathode gun). An electron gun which derives its electrons from a heated filament which may also serve as the cathode.

thermionic emission—the ejection of a stream of electrons from a hot cathode, usually under the influence of an electrostatic field.

thermocouple—two dissimilar electrical conductors so joined as to produce a thermal electromotive force when the junctions are at different temperatures.

thermocouple vacuum gage—a thermal conductivity or hot-wire gage in which the temperature of an electrically heated fine wire varies as the thermal conductivity of the residual gas. The thermocouple measures the temperature change.

thermoelectric pyrometer—a device with which temperatures are measured by utilizing the thermoelectric effects. In its simplest form, it consists of a thermocouple of two dissimilar metals which develop an emf when the junctions are at different temperatures and an instrument for measuring the emf developed by the thermocouple.

thermomechanical process, *n*—controlled thermal and deformation treatment performed at an elevated temperature.

threshold setting, in image analysis—the selected range of gray levels corresponding to a constituent in the field of the view.

tie line—in a binary or higher order phase diagram, an isothermal, isobaric straight line connecting the compositions of a pair of conjugate phases.

tie tetrahedron—in a quaternary or higher order phase diagram, an isothermal, isobaric four-cornered space figure connecting the compositions of four conjugate phases.

tie triangle—in a ternary or higher order phase diagram, an isothermal, isobaric plane three-cornered, straight-sided figure connecting the compositions of three conjugate phases.

time-temperature curve—in thermal analysis, a curve produced by plotting time against the temperature.

traceability—the ability to demonstrate by means of an unbroken chain of comparisons that a measurement is in agreement within acceptable limits of uncertainty with comparable nationally or internationally recognized standards.

transcrystalline cracking—cracking or fracturing which occurs through or across a crystal; intracrystalline cracking.

transformation temperature—the temperature at which a change in phase occurs. The term is sometimes used to denote the limiting temperature of a transformation range. Sometimes incorrectly and loosely referred to as Critical Point.

transition curve—in a P-T diagram, the locus of the temperature and pressure values at which a congruent equilibrium between two solid phases exists.

transition phase—a non-equilibrium state that appears in a chemical system in the course of transformation between two equilibrium states.

transition point—at a stated pressure, the temperature, or at a stated temperature, the pressure, at which two solid phases exist in congruent equilibrium, that is, an allotropic transformation temperature, or pressure.

transition structure—in precipitation from solid solution, a metastable precipitate which is coherent with the matrix.

transmission method—a method of X-ray or electron diffraction in which the recorded diffracted beams emerge on the same side of the specimen as the transmitted primary beam.

transmission microscope—a microscope in which the image forming rays pass through (are transmitted by) the specimen being observed.

transverse direction— See **cross direction**.

triclinic—having three axes of any length, none of the included angles being equal to one another or equal to 90°.

triple curve—in a P-T diagram, a line representing the sequence of pressure and temperature values among which two conjugate phases occur in univariant equilibrium.

triple point—in a P-T diagram, the temperature and pressure at which three phases occur in invariant equilibrium.

troostite (an obsolete and ill-defined term)—an unresolvable, fine aggregate of carbide and ferrite produced by tempering martensite at temperatures in the vicinity of 400 °C.

DISCUSSION—Term variously and erroneously applied to bainite and nodular fine pearlite. Confusion arose because of similarity in appearance among the three structures before the advent of high-power microscopy. With reference to tool steels, the term has been applied to highly tempered high-carbon martensite or to upper bainite.

twin bands—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 twin*—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.

T-X diagram—a two-dimensional, graphical representation of the isobaric phase relationships in a binary system; the coordinates of the graph are temperature and concentration.

ultramicroscopic—below the resolution of the microscope.

ultraviolet—invisible light radiation, adjacent to the violet end of the visible spectrum, with wavelengths from about 200 to 400 nm (nanometres).

unary system—composed of one component.

unbiased gun—(zero biased gun) an electron gun in which the cathode cap is at the same potential as the filament (see **self-biased gun**). This type of gun provides a low-intensity illumination with large angular aperture.

under-cooling—a decrease in temperature below that at which an equilibrium phase change exists, without the occurrence of the transformation.

unit cell—a parallelepiped element of crystal structure, containing a certain number of atoms, the repetition of which through space will build up the complete crystal. (See **lattice**.)

unit of structure (in crystals)—the unit cell, or the group of atoms associated with a unit cell.

univariant equilibrium—a stable state among a number of phases equal to one more than the number of components, that is, having one degree of freedom.

upper critical point—in a phase diagram, a specific value of composition, temperature and pressure, or combinations thereof, occurring as a maximum in temperature, or pressure, for the coexistence of two or more conjugate phases and at which the conjugate phases become identical.

vacuum lock—See **air lock**.

Vant Hoff's law—equilibrium shifts with increasing temperature so as to absorb heat, or with decreasing temperature so as to liberate heat.

vapor-deposited replica— See **replica**.

vaporization curve—in a P-T diagram the locus of pressure and temperature values at which a congruent liquid is in equilibrium with its vapor.

vaporization point—at a stated pressure, the temperature at which a congruent liquid is in equilibrium with its vapor, or, at a stated temperature, the pressure at which the same event occurs.

variability—also called "variance"; the number of degrees of freedom of a heterogeneous phase equilibrium.

variance—See **variability**.

verification—confirmation by examination and provision of evidence that an instrument, material, reference, or standard is in conformance with a specification.

vertical illumination—light incident on an object from the objective side such that smooth planes perpendicular to the optical axis of the objective appear bright.

Vickers—See **micro penetration tester**. In a more restricted sense, the 136° diamond pyramid indenter used in microindentation hardness tests.

voltage alignment— See **alignment**.

V-X diagram—a graphical representation of the isothermal or isobaric phase relationships in a binary system, the coordinates of the graph being specific volume and concentration.

wavelength (X-rays)—the minimum distance between points at which the electric vector of an electromagnetic wave has the same value, measured along the direction of propagation of the wave. It is equal to the velocity divided by the frequency. (See also **electron wavelength**.)

weld structure—the microstructure of a weld deposit and heat-affected base metal.

white (X-rays)—containing a large number of wavelengths.

widefield eyepiece—an eyepiece that permits the observation of an extended field of view of the specimen.

Widmannstätten structure—a precipitate structure, resulting from the precipitation of a new phase along certain crystallographic planes of the parent solid solution and characterized by a geometrical pattern appearance in the microstructure, originally observed in meteorites but readily produced in many other alloys with proper heat treatment.

work hardening—a change in the hardness of a material as a result of plastic deformation.

working distance—the distance between the surface of the specimen being examined and the front surface of the objective lens.

Wratten filter—the trade name for a specific type of color filter.

X-radiation—electromagnetic radiation of the same nature as visible light but having a wavelength approximately 1/1000 that of visible light.

X-ray tube—a device for the production of X-rays by the impact of high-speed electrons on a metal target.

X-rays—See **X-radiation**.

zone—any group of crystal planes which are all parallel to one line, called the zone axis.

APPENDIX

(Nonmandatory Information)

X1. ABBREVIATIONS AND ACRONYMS

X1.1 The following abbreviations are frequently used in the field of metallography.

Å	Angstrom unit.
K	X-rays (See K radiation.)

X1.2 The following abbreviations and acronyms are frequently used in the area of metallography.

AEM	analytical electron microscope
AES	auger electron spectroscopy
AFM	atomic force microscope
AGS	average grain size
AI	anisotropy index
AIA	automatic image analysis
ALA	as large as
APFEM	atomic probe field emission microscopy

ASM	acoustic scanning microscope
BEKP	back scattered electron kikuchi pattern
BSE	back scattered electrons
BSI	back scattered electron image
CBED	convergent beam electron diffraction
CCD	charge coupled device
CI	confidence interval
CL	confidence limit
CLM	cathoodo luminescence
CM	confocal microscopy
CV	coefficeient of variation
DIC	differential interference contrast
EBIC	electron beam induced current
EBSP	Electron Back Scattered Pattern
ECP	electron channeling pattern
EDS	energy dispersive spectroscopy
EDXA	energy dispersive X-ray analysis
EELS	electron energy loss spectroscopy
EMMA	electron microscopy micro analyzer
EMPA	electron microprobe micro analysis
EPMA	electron probe micro analysis
ESCA	electron spectroscopy for chemical analysis
FEM	field electron microscopy
FFT	fast Fourier transform
FIM	field ion microscopy
GCP	geometrically close-packed
HB	Brinell hardness number
HEED	high energy electron diffraction
HK	Knoop hardness number
HOLZ	high order laue zone
HR	Rockwell hardness number (requires a scale designation; for example HRC)
HV	Vickers hardness number
HVDF	high velocity oxy-fuel
IA	image analysis
IR	infrared
JK	Jernkontoret
LaB6	lanthanum-hexaboride cathode
LEED	low energy electron diffraction
LM	light microscopy
LOM	light optical microscopy
LP	lorentz polarization
LSCM	laser scanning confocal microscope
OCC ALA	occasional as large as
OCF	orientation correlation function
ODF	orientation distribution function
PAGS	prior austenite grain size
PFZ	precipitate free zone
RA	relative accuracy
ROI	region of interest
SAD	selected area diffraction
SAECP	selected area electron channeling pattern
SAED	selected area electron diffraction
SAM	scanning auger microscopy
SANS	small angle neutron scattering
SE	secondary electrons
SEI	secondary electron image
SEM	scanning electron microscope
SIM	scanning ion microprobe
SIMS	secondary ion mass spectroscopy
SLAM	scanning laser acoustic microscope
SRMN	Standard Reference Manual
STEM	scanning transmission electron microscopy
STIM	scanning transmission ion microscopy
STM	scanning tunneling microscope
TCP	topologically close-packed
TEM	transmission electron microscope
TOF SIMS	time-of-flight secondary ion mass spectrometer
TSC	thermal sprayed coating
UV	ultraviolet
WDS	wavelength dispersive spectrometry
WORM	write once read many
XRD	X-ray diffraction
XRF	X-ray fluorescence
XRM	X-ray microscopy
ZAF	Z-Absorption fluorescence
ZAP	zone axis pattern
ZOLZ	zero order laue zone

X1.3 The following are abbreviations of societies and institutes applicable to the field of metallography.

AIME	American Institute of Mining and Metallurgical Engineers
AISI	American Iron and Steel Institute
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
DIN	Deutsche Industrie Norm
ICDD	International Center for Diffraction Data (see JCPDS)
IEC	International Electrochemical Commission
IMS	International Metallographic Society
ISO	International Organization for Standardization
JCPDS	Joint Committee on Powder Diffraction Standards (see ICDD)
JIS	Japanese Industry Standard
MRS	Materials Research Society
MSA	Microscopy Society of America
NIST	National Institute for Standards & Technology
RMS	Royal Microscopical Society
SAE	Society of Automative Engineers
TMS	The Metals Society

BIBLIOGRAPHY

The following documents and publications may provide additional definitions of terminology in the field of metallography or closely related fields.

(1) *ASTM Standards:*
E44 Definitions of Terms Relating to the Heat Treatment of Metals
(2) E 175 Terminology of Microscopy
(3) E 456 Terminology Relating to Quality and Statistics
(4) *Other ASTM Literature:Compilation of ASTM Standard Definitions*
(5) *Other Publications:*
(6) *Dictionary of Light Microscopy*, 1989, Royal Microscopical Society.
(7) *Glossary of Metallurgical Terms and Engineering Tables*, 1984, ASM International.
(8) *Glossary of Microscopical Terms and Definitions*, 2nd ed., 1989, New York Microscopical Society.