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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E80 Recommended Practice for Dilatometric Analysis of Metallic Materials; Replaced by E 228 (Withdrawn 1986)[3]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E1122 Practice for Obtaining JK Inclusion Ratings Using Automatic Image Analysis (Withdrawn 2006)[3]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:—

$$n\lambda = 2d\sin\theta \qquad (2)$$

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:

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

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.