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Laboratory Safety

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Appendix 1

Glossary

Acceptor	a type of impurity atom in a semiconductor that removes electrons from the valence band and thereby creates mobile holes in the valence band.
Alloy	a solid comprising two or more elements that has metallic properties.
Amphibole	a class of silicate minerals that have double chains of fused silicate [$(SiO_4)^{4-}$] tetrahedra.
Anisotropy	a property that varies with direction.
Annealing	heating a solid at temperatures of generally one-half to two-thirds of the melting point on the kelvin scale, followed by slow cooling. This process allows some atomic rearrangement, removing some defects, and thereby improving the crystallinity of the solid.
Antifluorite structure	an (expanded) face-centered cubic array of anions, with cations in all of the tetrahedral holes (the reverse of the fluorite structure). Li_2O has the antifluorite structure.
Atomic force microscope	an instrument that can image atoms and operates by sensing the force between surface atoms of a sample and a probe tip.

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Austenite	(1) the high-temperature phase of iron (also known as γ-iron), which is stable between ~900 and 1400 °C; (2) the high temperature phase in a two-phase systems that undergoes a martensitic phase transition (NiTi, for example).
Band	a collection of orbitals, each delocalized throughout the solid, that are so closely spaced in energy as to be nearly continuous.
Band gap	the energy separation between the top of the valence band and the bottom of the conduction band.
Berthollide compounds	materials that have variable compositions, such as NbH_x, where x can vary from 0.64 to 1.0.
Biasing	applying a voltage, often done to alter the electrical and optical output of a device such as a light-emitting diode (LED).
Biodegradable	capable of being decomposed in the environment.
Body-centered cubic (bcc)	a type of unit cell that has identical atoms at the corners of a cube and in the center of the cube.
Bohr radius	the distance between the nucleus and the first electronic orbital in the Bohr model of the hydrogen atom (the most probable distance for finding the electron in the hydrogen atom ground state in quantum mechanics). It is a unit of distance equal to ~0.53 Å.
Buckminsterfullerene	an allotropic form of carbon with the formula C_{60}. The molecule has the same shape and symmetry as a soccer ball.
Carrier concentration	the number of charge carriers per unit volume, often expressed in units of carriers (electrons, holes or ions) per cubic centimeter.
Cesium chloride structure	a structure formed by two interpenetrating simple cubic arrays. The unit cell consists of a cube having one kind of atom at the corners of the cube and a second kind of atom in the center.

Chemical vapor deposition (CVD)	a method for growing solids; typically gaseous precursor species are decomposed at a heated substrate, after which they deposit the desired material.
Conductance	the ability to carry current. It has units of ohm^{-1}, also called mhos or siemens, and is the reciprocal of resistance.
Conducting polymers	long-chain molecules, usually possessing extensive conjugation, that are capable of carrying current.
Conduction band	a band that when partially occupied by mobile electrons, permits their net movement in a particular direction, corresponding to the flow of electricity through the solid.
Constructive interference	the condition that occurs when two (or more) waves are in phase and interfere to give a wave with enhanced amplitude and intensity.
Cooper pairs	electron pairs that form in superconducting solids; formation of these pairs is a characteristic of the phase change that occurs at the critical temperature of the solid.
Critical current (J_c)	the highest current density at which the superconducting state may be maintained in a solid.
Critical field (H_c)	the highest magnetic field strength at which the superconducting state may be maintained in a solid.
Critical temperature (T_c)	the highest temperature at which the superconducting state may be maintained in a solid.
Crystalline solid	a solid that is composed of identical patterns (unit cells) of atoms, ions, and/or molecules that repeat continuously until the boundaries of the solid are reached.
Cubic close packed (ccp)	planes of close-packed atoms or ions that are stacked ABCABC....

Cubic hole	the hole formed in the center of eight atoms or ions that sit at the corners of a cube.
Curie temperature	the temperature above which thermal energy is sufficient to destroy the alignment of electron spins in a ferromagnetic material, and thus cause the material to become paramagnetic.
Czochralski crystal growth	a technique for growing ultrapure crystals from a melt of the same composition.
De Broglie wavelength	the wavelength associated with a particle due to its momentum. $\lambda = h/mv$, where λ is the de Broglie wavelength, h is Planck's constant, m is the mass of the particle, and v is its velocity.
Destructive interference	the condition that occurs when two (or more) waves are out of phase and interfere to produce a wave with smaller amplitude and intensity.
Diamagnetism	the magnetic property that results when all electrons in a material are paired, a condition causing the material to be slightly repelled by a magnetic field.
Dielectric constant	a measure of the ease with which a material is polarized by an electric field.
Diffraction	the scattering of light from a regular array, producing constructive and destructive interference. In crystallography, diffraction of X-rays is observed from the regular and repeating arrays of atoms in a crystalline solid.
Diode laser	a type of laser in which a p–n semiconductor junction is used to produce coherent light.
Dislocation	a type of one-dimensional (line) defect in a crystal. Movement of dislocations facilitates the motion of atoms in a crystal.
Domain	a microstructural region within a sample. For example, in a ferromagnetic material, a region in which the electron spins are aligned.
Donor	a type of impurity atom in a semiconductor that adds mobile electrons to the conduction band.

Dopant	an impurity atom that is deliberately added to a semiconductor.
Ductile	the ability of a material to undergo changes in shape (plastic deformation), such as being drawn into wires, rather than breaking; a term often applied to metals.
Elastic deformation	a temporary change in shape in response to a stress; removal of the stress restores the original shape (contrast plastic deformation).
Electrical conductivity	the ability of a material to carry an electric current. The symbol for conductivity is σ, and it has units of $ohm^{-1}\ cm^{-1}$. It is also the reciprocal of resistivity.
Epitaxial growth	the growth of one crystalline material on a substrate of another crystalline material in such a way that the deposited atoms are in registry with atoms on the surface of the substrate.
F-center	a type of defect in ionic compounds in which an electron is trapped in an anion (often halide) vacancy in the crystal. It is also sometimes called a color center.
Face-centered cubic (fcc)	a type of unit cell in which there are identical atoms at the corners and in the centers of the faces of a cube. Identical to the cubic close-packed (ccp) arrangement.
Fermi level	the thermodynamic electrochemical potential or the energy in a solid, below which it is more likely that the electronic states are occupied with electrons and above which it is more likely that the electronic states are not occupied; because it is defined statistically, there may or may not be an energy level at this energy.
Ferrite	the low-temperature phase of iron, also known as α-iron; stable below ~900 °C.
Ferrofluid	a suspension of a magnetic solid like Fe_3O_4 (Fe_3O_4 is actually ferrimagnetic, *see* Chapter 2) in a liquid that responds to an external magnetic field.

Ferrimagnetism	a phenomenon in which the internal magnetic moments of multiple spin sets of unpaired electrons within the domain of the solid do not cancel and therefore leave a net spin.
Ferromagnetism	a phenomenon in which the internal magnetic moments of unpaired electrons within a domain of the solid are aligned and act cooperatively.
Fluorite	the common name for the mineral CaF_2.
Fluorite structure	a structure in which there is a face-centered cubic array of cations and a simple cubic array of anions. This is the structure of CaF_2.
Flux	a melted sample of a material, usually a metal or salt, that is used as a solvent for a reaction or crystallization, often at elevated temperature.
Frenkel defect	a type of defect in a solid in which an atom or ion (usually the smaller cation) is found in an interstitial site rather than in its normal site.
Garnet	a family of complex oxides with the general formula $C_3A_2D_3O_{12}$, where the C cations occupy dodecahedral sites, the A cations occupy octahedral sites, and the D cations occupy tetrahedral sites in the crystal structure—an example is $Gd_3Fe_5O_{12}$, where Fe(III) ions occupy both A and D sites.
Grain	a small crystalline region randomly oriented within the bulk crystal.
Grain boundary	the intersection of two grains within a crystal.
Hexagonal close packed (hcp)	a type of crystalline structure in which close-packed layers of atoms or ions are stacked ABABAB....
Hole (h^+)	a fictitious mobile particle that behaves as though it is a positively charged particle; holes are produced in the valence band when electrons from the valence band are promoted to the conduction band or to an acceptor dopant.

Hole	an empty site in a crystalline solid (*see* cubic hole, octahedral hole, or tetrahedral hole).
Hydrodesulfurization (HDS)	removal of sulfur from petroleum feedstocks.
Hysteresis	a phenomenon in which some property of a material depends on the sample's history; for example, the structure and electrical conductivity of a material such as NiTi over the temperature range corresponding to its phase change may depend on whether the sample was heated or cooled to reach its current temperature.
Insulator	a type of material having a lower energy valence band that is nearly completely filled with electrons and a higher energy conduction band that is nearly completely empty of electrons as a result of a large energy gap between the two bands. Such materials are poor conductors of electricity.
Interstitial atom	an atom in a normally unoccupied hole between atoms in a crystal.
Isomorphous substitution	the replacement of one atom with another of similar size such that there is no significant change in the structure.
Isotropic	a property that is the same in any direction.
Law of Dulong and Petit	the observation that many metallic elements have molar heat capacities of 25 J/mol-deg at and above room temperature; used as an early method for determining atomic weights.
Light-emitting diode (LED)	a semiconductor p–n junction that is optimized to release light of approximately the band-gap energy when electrons fall from the conduction band to the valence band under forward bias.
Malleable	able to be shaped by hammering, pressing, or bending; a term often applied to metals.

Martensite	the original name given to the hard material formed during the quenching of steel, it more generally refers to the low-temperature phase in a martensitic phase transformation.
Material life cycle	the extraction of raw materials, synthesis and processing, product preparation, use, and waste disposal considerations that are related to the development of a useful material.
Materials chemistry	the study of the synthesis, processing, and chemical and physical properties of solids.
Meissner effect	the expulsion of a magnetic field (perfect diamagnetism) from a superconductor.
Metal	a material with a partially filled energy band. Metals are generally malleable, ductile, good reflectors of electromagnetic radiation, and good conductors of heat and electricity. Metals are usually identified by having electrical conductivities that decrease with increasing temperature.
Mho	a unit of conductance; the reciprocal of ohm.
Microstructure	the arrangement of atoms on a scale of micrometers (10^{-6} m).
Molecular beam epitaxy (MBE)	a technique for growing solids, atomic layer by atomic layer, based on precursors delivered to a target substrate by collimated beams of atoms or molecules.
Molybdenite	the common name for the mineral MoS_2, whose layered structure allows it to be used as a lubricant.
n-type semiconductor	a semiconductor that has been doped with an electron donor such that the number of mobile conduction band electrons is greater than the number of mobile valence band holes at thermal equilibrium.
Nanostructure	the arrangement of atoms on a scale of nanometers (10^{-9} m).

Nitinol	a "smart material" that is an alloy with the formula NiTi; the solid has shape-memory applications.
Nonstoichiometric compounds	another name for compounds of variable composition; such substances are also called berthollide compounds. In these materials a variable amount of atoms is present in the holes of a host structure.
Octahedral hole	the hole formed in the center of six atoms or ions sitting at the corners of an octahedron.
Optical fiber	a glass or plastic cable capable of transmitting light with high efficiency.
Order-disorder phase change	a phase change that involves reorientation or repositioning of the atoms in a structure from a more orderly arrangement to a more random arrangement or vice versa.
p–n junction	the region of contact on the atomic scale between a p-type and an n-type semiconductor.
p-type semiconductor	a semiconductor that has been doped with an electron acceptor so that the number of mobile valence-band holes exceeds the number of mobile conduction-band electrons at thermal equilibrium.
Paramagnetism	a phenomenon characterized by an attraction of a material to a magnetic field due to the presence of unpaired electrons.
Perovskite	the mineral $CaTiO_3$; also, a class of structures that have the perovskite structure.
Phonons	quantized, collective vibrations of the atoms in a solid.
Piezoelectricity	a phenomenon whereby the application of an electric field to certain solids causes them to change shape. Conversely, their mechanical deformation produces an electrical signal.
Pinning	the process of preventing the movement of atoms or defects within a crystal.

Pixel	the smallest dot that can be displayed on a computer screen or output (picture element).
Plastic deformation	the ability to re-shape a material because of the sliding of atomic planes in a crystal relative to one another (contract elastic deformation).
Point defect	a zero-dimensional defect such as a vacancy (missing atom), substitutional impurity, or interstitial atom.
Poisson ratio	a mechanical property of a material, $\mu = \frac{\text{fractional decrease in width}}{\text{fractional increase in length}} = \frac{\Delta w/w}{\Delta l/l}$
Polymorph	a substance that crystallizes in two or more different forms, such as the wurtzite and sphalerite forms of ZnS or graphite, diamond, and fullerene forms of C.
Precipitation hardening	generation of a precipitate of an impurity phase within a host crystal that serves to roughen slip planes and makes the motion of dislocations more difficult. This process generally results in harder but more brittle materials.
Pyroxene	a class of silicate minerals that have a one-dimensional single chain of linked silicate tetrahedra.
Quenching	the process of quickly immersing a hot object in a cold medium like water or liquid nitrogen to lock in a particular structural arrangement of atoms. Also the rapid heating of a superconducting electromagnet when the superconductivity is lost.
Radius ratio	in ionic compounds, the radius of the cation divided by the radius of the anion.
Re-entrant foam	a polymer foam that has been isotropically compressed at an elevated temperature to produce a solid with a negative Poisson ratio
Reflectivity	the amount of light reflected relative to the total incident light.

Resistance	opposition to the flow of electric current. It has the symbol Ω and units of ohms and is the reciprocal of conductance.
Resistivity	the reciprocal of conductivity, given the symbol ρ. It is related to resistance by the equation $R = \rho L/A$, where R is the resistance, ρ is the resistivity, L is the length of the wire, and A is its cross-sectional area.
Rock salt structure	the common name for NaCl and other salts having the same structure consisting of two interpenetrating arrays of face-centered cubic cations and anions.
Scanning tunneling microscope (STM)	an instrument that is capable of imaging individual atoms through the quantum mechanical tunneling of electrons between an electrically conducting atomic tip and the substrate to be imaged.
Schottky defect	a type of vacancy defect in an ionic compound, consisting of a pair of vacant cation and anion sites.
Semiconductor	a type of material having a lower energy valence band that is nearly completely filled with electrons and a higher energy conduction band that is nearly completely empty of electrons, with a modest energy gap between the two bands. Such materials generally exhibit electrical conductivity that increases with temperature because of an increase in the number of charge carriers. *See also* n-type semiconductor, p-type semiconductor.
Shear	the application of antiparallel forces to opposite sides of an object.
Siemen	a unit of conductance; equivalent to a ohm^{-1} or a mho.
Silicate ion	the SiO_4^{4-} ion.
Simple cubic	a type of unit cell in which there are identical atoms at the corners of a cube.

Sintering	a method for increasing the density of a polycrystalline or powdered material by heating it to near its melting point. This step shrinks or removes pores and increases grain size.
Slip plane	a plane of atoms that is able to slide past an adjacent plane of atoms with relative ease.
Smart material	a material that is capable of sensing changes in its environment and responding to them.
Sodium chloride structure	a structure formed by interpenetrating face-centered cubic arrays of cations and anions (also called rock salt structure).
Solid solution (substitutional)	a homogeneous pure solid in which one type of atom (or ion) has randomly substituted for a similar atom (or ion) in a structure.
Solid solution hardening	improving the hardness of a metal by adding impurity atoms that are either much larger or smaller than the host atoms. This process roughens the slip planes and makes the motion of dislocations more difficult.
Specific heat capacity	the amount of heat it takes to raise 1 g of a substance by 1 °C.
Sphalerite	the name for the mineral ZnS (also called zinc blende) in which there is a face-centered cubic array of anions with cations in half of the tetrahedral holes.
Sputtering	a preparative technique in which gaseous ions bombard a metal cathode, and thereby enable the freed metal atoms to form a metallic coating on a substrate.
SQUID	superconducting quantum interference device. This device, based on junctions of a superconductor with an insulator, provides a sensitive method for detecting magnetic fields.
SSMK	abbreviation used for the Solid-State Model Kit.

Substitutional stoichiometry	substitution of one atom or ion for another without significantly changing the overall structure.
Surfactant	a material such as a soap or detergent that reduces surface tension; the molecule typically has a polar head and a nonpolar tail.
Tetrahedral hole	the hole formed in the center of four atoms or ions sitting at the corners of a tetrahedron.
Thermal conductivity	the transfer of heat via the vibration of atoms.
Thermal spray coating	a process in which a metal, ceramic, or plastic material is heated, melted, and sprayed onto a surface. The particles of the material flatten on impact and bond to the surface.
Thermoluminescence	light energy that is released when a sample is exposed to heat.
Tunneling	the movement of an electron due to its wave nature through a classical barrier.
Unit cell	a repeating unit of an extended structure; a parallelepiped in three dimensions, whose translation along each of the edges of the unit cell by the length of the edge, allows the entire structure to be constructed.
Vacancy	an absent atom or ion in a crystal.
Valence band	the highest energy band that lies at the bottom at the band gap.
Van der Waals forces	weak interatomic forces that dominate interactions between nonpolar molecules or atoms.
Variable stoichiometry	a situation in which varying amounts of an atom are present in the interstices of a host compound.
Variant	a possible direction for shifting or shearing in a crystal.

Wurtzite	a mineral form of ZnS in which the anions form a hexagonal close-packed arrangement and the cations are in half of the tetrahedral holes.
Zeolite	an aluminosilicate that has a framework of tetrahedral aluminate and silicate units that form a series of tunnels and cavities.
Zinc blende	a common name for the mineral ZnS (also called sphalerite) in which the anions form a face-centered cubic arrangement and the cations are in half of the tetrahedral holes.
Zinc blende structure	a structure in which there is a face-centered cubic array of anions with cations in half of the tetrahedral holes.
Zone refining	a process for obtaining pure materials that involves melting a small region of the impure solid and gradually moving the molten zone. The impurities tend to concentrate in the melt, and the recrystallized region is highly purified.